> [i]t is suggested that […] any earmarking, any efforts to reserve areas of outer space for exclusive use would be contrary to the aim and purpose of the Treaty; that it is only when the exploration and use takes place in effect that States should be allowed to exercise certain rights over such areas.[158]

Far from being a matter of conjecture that is vaguely implied by the aim and purpose of the space treaties, our understanding of property as distinguished by exclusion, even without use, reveals that 'earmarking' is, in a very literal way, what is proscribed by Article II of the Outer Space Treaty. If this entails that no claims can be made with respect to resources that have never been used, it also implies that, no matter how extensive and lengthy instances of actual use may be, they cannot result in property rights that remain after use. This is exactly what is meant by the 'by means of use' modality in Article II of the Outer Space Treaty and Article 11 (2) of the Moon Agreement.[159]

To be sure, some form of 'preferential rights' may be acquired by a state on the basis of its previous efforts and activities. Just as the Moon Agreement recognizes that the efforts made by the first one to exploit certain resources may be reflected in the distribution of benefits from this exploitation,[160] space law doctrine generally recognizes that a state actually using a resource may be granted some form of preferential treatment, in addition to the rights of non-interfered use that are secured through the exercise of its freedom to use.[161] These rights are invariably limited by the duration of the actual use, however, and in particular should not be mistaken

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[158] D. Goedhuis, *Some Legal Problems Arising From the Utilization of Outer Space*, in REPORT OF THE FIFTY-FORTH CONFERENCE, FROM 23-29 AUGUST 1970 IN THE HAGUE, NETHERLANDS 430 fn. 40 & 38 (ILA 1970). The suggestion can be traced back to F. Vallat, *The Outer Space Treaty*, 1969 AERONAUTICAL J. 754 (1969).

[159] S. Freeland and R.S. Jakhu, *[Outer Space Treaty:] Article II*, in COLOGNE COMMENTARY, VOL. I: OUTER SPACE TREATY 44-63 (S. Hobe, B. Schmidt-Tedd and K.-U. Schrogl, eds., 2009). *See* also the interpretation offered by the representative of Belgium to the UNCOPUOS at the time of adoption of the Outer Space Treaty, who construed it as meaning that use would not produce a condition of sovereignty, nor would it *lead to the creation of titles* to property in private law. UNCOPUOS Leg. Subcomm., *Summary Record of the Seventy-first Meeting*, U.N. Doc. A/AC.105/C.2/SR.71 (Aug. 4, 1966) and Addendum 1, at 7 U.N. Doc. U.N. Doc. A/AC.105/C.2/SR.71 add. 1 (Oct. 21, 1966).

[160] Moon Agreement, Art. 11 (7), sub d.

[161] Zhukov agrees that states arriving first on a celestial body should have some minimal greater rights with respect thereto than others. See comments in Smirnoff, *supra* note 117, 22.

for watered-down property rights. In his discussion of the regulation of activities on celestial bodies, Markoff concedes that the legitimate interests of the state exploiting a resource should be translated into certain preferential rights. However:

> [l]es droits préférentiels de nature exclusive ne peuvent pas se transformer en droits acquis. Ils ne peuvent exister que durant la période de fonctionnement de la station planétaire. Une fois que l'objet spatial s'est envolé vers la Terre, ou la station démontée, déplacée à un autre endroit ou simplement supprimée, soit par l'achèvement des travaux, soit par l'abandon des activités et le transfert des installations ailleurs, l'Etat compétent ne peut plus revendiquer aucun droit d'établissement sur le même site. Celui-ci peut légitimement être engagé, par l'objet spatial appartenant à un autre Etat.[162]

Valters discerns between lawful use and unlawful appropriation on a similar basis, by noting that "certainly a state cannot legally claim a particular orbital 'parking slot' merely by virtue of having had a satellite in that 'parking slot.'"[163] Lachs' views on the regime of space resources, too, closely resemble a recognition of the right to use without resulting in a future title to exclusive rights:

> [n]either priority in discovery nor the mastery of technical facilities could constitute a title to exclusive rights in this field [of the use and exploitation of natural wealth and resources on celestial bodies]. Those who command these special possibilities may no doubt be entitled to claim that their efforts leading to the discovery and use of the facilities or resources should duly be taken into account. This could not, however, affect the basic principles: that the Moon and celestial bodies are 'not subject to national appropriation,' and that the exploration and use of outer space and celestial bodies 'shall be carried out for the benefit and in the interest of all countries.'[164]

The author adds that, while the fact that the actual use of space is still the privilege of a minority of states cannot be altered

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[162] Markoff, *supra* note 104, 657.

[163] Valters, *Perspectives in the Emerging Law of Satellite Communication*, 5 STAN. J. INT'L STUD. 66 (1970).

[164] Lachs, *supra* note 40, 45.

by space law, "what the latter can do, however, is to refuse to sanction situations which may close the door to equal rights and benefits for all States in the future."[165] As such, the proscription of appropriation remains as a guarantee for inclusive use without, however, limiting the freedom to use outer space. Or, in the words of Doyle: "[t]he fact that the use of a celestial body may not justify a declaration of national sovereignty over that body is not the same as saying 'because one cannot declare sovereignty one cannot use.' The OST says the opposite."[166] Whatever rights are acquired through use, they remain limited to the duration of the use. And while the duration of this use may be indefinite, this does not pose a problem in light of Article II as such, for the use cannot, legally, result in property rights.[167]

Hence, it is clear that the exploitation of space resources does not involve, *nor does it require*, a *right* to exclude others, for exclusion in space does not follow from an exercise of authority other than the authority inherent in the universal freedom to use outer space. There is no *option* to exclude others when exploiting resources, for the enforceability of the right not to be interfered with exists only when the resource is actually and lawfully in use, in which case the exclusion of others derives from the actuality of the use itself.

V. CONCLUSION

Our renewed understanding of the concept of property rights allows us to reconcile the practice of tangible resource exploitation as conceived by private space enterprises with the language of the existing international treaties on the subject. Any allegations of unlawfulness of the exploitation of material resources on celestial bodies for reason of their exclusivity through consumption fail to take into account the link with the right to use outer space and the au-

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[165] *Id*. at 43.

[166] Doyle, *supra* note 12, 114. *See also* S.E. Doyle, *Issues of Sovereignty and Private Property* in LUFT- UND WELTRAUMRECHT IM 21. JAHRHUNDERT: LIBER AMICORUM KARL-HEINZ BÖCKSTIEGEL 315 (M. Benkö and W. Kroll, eds., 2001).

[167] *See* C.Q. CHRISTOL, SPACE LAW: PAST, PRESENT, AND FUTURE 113 (1991) ("Article 2 of the 1967 Principles Treaty [*sic*] means that the early and continuing use by the United States of the orbit/spectrum resource does not convert the 'first-come, first-served' doctrine into a base upon which exclusive, *i.e.* sovereign, rights may be asserted").

thority component of property. Hence, Fasan's contention that "destruction of an object […] is the ultimate appropriation,"[168] though intuitively sensible, proves utterly misleading. For consumption *through the exercise of a universal freedom to use* is not the same as destruction emanating from a *right to* destroy, without realization of the resource's economic potential. The latter is legally speaking an exponent of the right not to use, in that it only mirrors the exclusivist consequences of consumption, without the utilitarian justification therefor. It can be explained, not as an exercise of the freedom to use, but only with reference to the right not to use as the defining emanation of the particular relationship between exclusion and use so characteristic of property.

Which brings us back to the property implications of permanent exclusion following the consumptive use of tangible resources. Indefinite exclusion of others through instantaneous use of resources by one is particularly problematic in a legal regime characterized by the absence of property, for the consumption appears to sever the link between exclusion and use. When discussing the regime on the use of orbital positions, limitations in time are sometimes offered as a safeguard to restrict the impact on others of the continued use of limited resources by some. An isolated focus on the duration of the exclusion, without contemplating its original link with actual use, as a ground for raising suspicions of *de facto* appropriation, both in the context of orbital positions and the use of consumable resources, is thoroughly misplaced, however, as it rests on the *a contrario* assumption that property necessarily entails an element of longevity or permanence. This of course is dubious at best, as is demonstrated, for example, by the regime of intellectual property rights. Though always limited in time, there is no doubt that these rights retain their qualification as property.[169]

If the above shows that property rights can exist even when limited in time, it also implies that the permanent nature of exclusion does not provide an insurmountable hurdle for dispelling the

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[168] E. Fasan, *Asteroids and Other Celestial Bodies - Some Legal Differences*, 26 J. SPACE L. 39 (1998) (reiterated in Lee, *supra* note 13, 188. *See* also L. VIIKARI, FROM MANGANESE NODULES TO LUNAR REGOLITH: A COMPARATIVE LEGAL STUDY OF THE UTILIZATION OF NATURAL RESOURCES IN THE DEEP SEABED AND OUTER SPACE 109 (2002).

[169] *See* Penner, *supra* note 23, 761.

existence of property rights in material resources. Again, what matters is the nature of the relation between the exclusion and use of the resource at hand to discern whether the exploitation in question rises to the level of property. Just as the material or immaterial nature of the thing owned does not alter the legal requirements for ownership, the fact that consumptive destruction entails indefinite exclusion does not change the legal nature of the relationship between the user and non-users. For while the exclusion is not limited to the period of actual use - which is, after all, only momentary - there remains a definite link between the actual use and the exclusion, in that the latter is tolerated only as a precondition for, and consequence of, the exercise of the freedom to use outer space. Hence, if we accept that the exploitation of resources is allowed, in general, under current space law provisions, there is no reason to bar the consumption of resources from celestial bodies in particular, for objections thereto appear to rest on an incorrect understanding of the national appropriation proscription as barring destructive use of resources rather than destruction without use.

Returning to the recent legal developments that inspired this article, our approach to property rights means that the friction created between US space commercial legislation and international space law, through the adoption of the Space Resource Act, appears to be largely theoretical, if our concern is one of violating the non-appropriation provision through the act of resource extraction. To the extent that legal certainty for attracting commercial investments in a high-risk endeavour was the driver for the 2015 Act, the introduction of property rights over removed resources seems less decisive than the, ultimately abandoned, regime of civil action for relief from harmful interference in case of competing activities relating to the same resource. Indeed, granting property rights after extraction would still leave unaddressed the crucial period leading up to the actual point of resource exploitation, as well as the issue of exclusivity over the mining site as such during this activity.

Hence, what is needed is a clear, simple and predictable regime dealing with competing claims over mining sites on celestial bodies both before and during the excavation of valuable resources. Previous versions of the Space Resource Act already contained some indications as to how we should proceed in setting up this regime, though it understandably only dealt with competition between US

citizens. The plans already announced by Luxembourg and, possibly, the United Arab Emirates, to promulgate legislation covering the exploitation of resources from celestial bodies indicates that we will also need international initiatives in this respect sooner rather than later. The general exchange of views expected to take place on the occasion of the 2017 session of the Legal Subcommittee of the UN COPUOS may be a first step in this direction, though the road ahead remains long and perilous.

GREEN FOR LIFTOFF: STRUCTURAL CHANGES FOR ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY IN SPACE LAUNCHING

*Justin Fisch**

I. INTRODUCTION

A. Rationale of research

Space has never been a particularly "green" industry, whether on Earth or in outer space. On our home planet, the space sector has damaged waterways, littered debris, caused nuclear pollution, and released countless harmful chemicals into every layer of the atmosphere. [1] In outer space, the industry has left thousands of dangerous pieces of debris, impacted celestial bodies, and contaminated a previously unblemished natural environment, all within a span of six decades.

Environmental damage in the space sector is often analogized to harms occurring in the air, the high seas, the deep seas, or even, Antarctica.[2] Garrett Hardin's Tragedy of the Commons helps explain this phenomenon, wherein individual activities account for

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[1] Executive Summary, Final Report, *ecoSpace: Initiatives for Environmentally Sustainable Launch Activities*, International Space University: Strasbourg, 2010.

[2] LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE 206 (2008).

little gross environmental impact, but accumulated damage renders a common space environmentally distraught.[3] As such, the history of space exploration has seen individual missions derive benefits from environmentally-harmful activity, while causing an overall detriment to future space exploitation.[4] For this reason, the international community has agreed on common rules to safeguard the future of human activities in the space environment, broadly encapsulated in Article IX of the 1967 Outer Space Treaty, banning contamination that had the potential to cause harmful interference with human space activities or life on Earth.[5]

Yet where international regulation has made a modicum of difference in the sphere of outer space,[6] the terrestrial impacts of space activity have been largely ignored.[7] Oversight of the Earth's biosphere is thus left to national and local jurisdiction, with some international oversight in the form of bilateral treaties, settlement agreements, and the broad provisions of the Liability Convention.[8]

This lacuna in international environmental space law presents vulnerability in environmental protection on a global scale. Due to the highly competitive and expensive nature of the space sector, customers—commercial and governmental—seek out the most remunerative launch opportunities in an international industry.[9] The lack of space launch regulation has the potential to lead to a "race to the bottom"[10] in the industry, enticing entrepreneurs to take

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[3] Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

[4] Viikari, *supra* note 2, at 4.

[5] Although scholars will argue that the considerations brought about by international regulation on the law of space are exclusively meant to safeguard future human activity, and have little concern for the natural space environment. *See generally*, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *opened for signature* Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

[6] Many publicists would argue that international space law is not at all environmental. *See, e.g.*, Viikari, *supra* note 2.

[7] *Id.* at 52.

[8] Convention on International Liability for Damage Caused by Space Objects, *opened for signature* Mar. 29 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187 [hereinafter Liability Convention]. These provisions find their base in the Outer Space Treaty, *supra* note 5.

[9] Viikari, *supra* note 2 at 323.

[10] For further insight on the socio-economical "race to the bottom" phenomenon, *see* Michael Ashby, Zach Goldstein, & Carly Van Dort, *A 'Race to the Bottom': The Adverse Effects of Globalization on Environmental Standard*, University of Michigan Global

their launch business to the most economical and least regulated launch sites,[11] essentially creating a "flag of convenience" in the global space industry.[12]

In accordance with the precautionary principle in environmental law,[13] policy and regulatory research is needed in order to prevent a race to the bottom in the space sector. The research proposed is current and topical, in that ten countries (and counting) now possess space launch capabilities with indigenous rockets.[14] Yet only five of these states have been properly surveyed for adequate environmental protection in the launch sector.[15] In accordance with the scientific uncertainty, as well as technical and political challenges that underlie the space sector, the rationale of this paper is to briefly canvass the existing policy and legal framework at a crucial time for the industry.

B. Objective of Research

The research will focus on the environmental impacts of space launches, drawing on the historically diverse uses of space, from its military beginnings to its current commercial reality. The paper strives to offer a brief comparative approach to national and local environmental laws with regard to space launches, in order to properly situate them within the appropriate international legal framework.

Change, http://www.globalchange.umich.edu/globalchange2/current/workspace/Sect007/s7g3/index.htm.

[11] Armel Kerrest, Space Debris, *Remarks on Current Legal Issues*, 2 Proc. of the Third European Conf. on Space Debris 869 (2001).

[12] Flags of convenience are an issue that the domains of air and space law have been largely able to avoid. Contrastingly, the maritime industry has wholly suffered from flags of convenience: *See, e.g.*, GBENGA ODUNTAN, SOVEREIGNTY AND JURISDICTION IN THE AIRSPACE AND OUTER SPACE 75 (2012).

[13] Stephan Hobe, Book Review, 26 Space Policy 128 (2010) (reviewing LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE (2008)).

[14] Jonathan O'Callaghan, Space Answers, How many countries have rockets capable of reaching space? (Mar. 21, 2013), http://www.spaceanswers.com/space-exploration/how-many-countries-have-rockets-capable-of-reaching-space/.

[15] ISU Final Report, *supra* note 1.

Following, the paper's objective is to present a broad survey of international environmental protections and regulation, both binding and not, while suggesting room for improvement on international protocol. The paper concludes with an outlook to the future of impact assessments and regulation for space launches, while highlighting best practices and room for improvement.

It is important to note that this article is limited to policy regarding protection of the terrestrial environment in launch settings. Whereas environmental problems in outer space are also vital to the sustainability of the industry, they have been well surveyed by various authors.[16] Moreover, the paper's objective is to offer a critical analysis of regulation as a precondition for launch site selection. Therefore, the piece will not address issues of space debris, nuclear contamination, and exobiological contamination not directly associated with launch settings.[17] In limiting the scope of the article, particular focus will be paid in local site affect, terrestrial impact assessment, ocean contamination, hazardous exhaust, and impact contamination from return to Earth.

II. LITERATURE REVIEW

A. *Background*

Literature on environmental aspects of space law is growing at a fast rate. Interest in the field comes from a variety of stakeholders, including academics, students, industry professionals, governments, and potential launch customers. Environmental analysis of space law comes from a various points of view, including scientific, engineering, technological, practical, political, legal, and business. The most common material in the field includes books, journal articles, public reports, commercial press pieces, and journalistic investigations. These second-hand analyses are complemented with a range of official documents, from acts and regulations to case law.

In order to specifically analyze the launch industry, a cross-disciplinary literature review was undertaken. Diverse scientific reports and industry publications were studied to understand the

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[16] Including, but not limited to Viikari, *supra* note 2; MATTHEW J KLEIMAN, THE LITTLE BOOK OF SPACE LAW (2013); and ISU Final Report, *supra* note 1.

[17] For further reading on these subjects, a fine reference is: Viikari, *supra* note 2.

technical challenges to green launching.[18] Following, a general read on international environmental law was done, so as to comprehend the place of space in this broad field.[19] Lastly, specific investigation on space law and its environmental applications was performed.[20]

The last portion of the review proved most challenging, as little has been written regarding the "environmental element" in space law.[21] Even more difficult proved to be narrowing the ambit of research to specific application of environmental considerations in space launches. As discussed in the Introduction, environmental application of space law is a large area, focused generally on outer space itself. Few authors have addressed the terrestrial impacts of space launches, to which this article seeks to add a modicum of detail.

B. Technical Challenges to Green Launches

Space launching is an inherently polluting industrial activity. From rocket manufacturing to attaining orbit, numerous environmental harms are committed. The concept of "green launching" seeks to minimize these harms so as best to protect the surrounding environment and pave the way (so to speak) for a sustainable industrial model in an era of growing space needs and activity.[22] In this section, we study three of the greatest environmental challenges affected the space launch industry: payload separation, fuel use, and failed launches.

1. Payload Separation

Planned environmental harm is that which is foreseen in the concept of the launch. The most common example in modern-day rocketry is payload separation, wherein stages gradually detach

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[18] *E.g.*, Kleiman, *supra* note 16.

[19] DANIEL BODANSKY, JUTTA BRUNNÉE, & ELLEN HEY, THE OXFORD HANDBOOK OF INTERNATIONAL ENVIRONMENTAL LAW (2007).

[20] Viikari, *supra* note 2.

[21] To borrow the term from Viikari, *id.*

[22] Kleiman, *supra* note 16.

from the intended orbit vehicle on its way to space.[23] Although research and development is underway to develop new rocket-less launch technologies, such as space elevators and mass drivers,[24] most current launch methods requite payload separation. The sole exception is Virgin Galactic's stratolaunch system.[25] However, this launch method is currently under development, and recently suffered a major drawback due to a failed launch in November 2014.[26]

Although dropped rocket stages are generally not considered a significant environmental contaminant by the launch industry, public opinion regarding perception of environmental responsibility is increasing.[27] Scientifically, payload separation is detrimental to the environment as a result of its impact back on Earth, following a split from the orbiting vehicle. Dropped payload can impact sea or land, depending on launch trajectory and launch site.[28] Currently, Russia and China have the most notable operations involved planned payload drops over land, from the Baikonur Cosmodome and Xichang Spaceport, respectively.[29] Whether coming down on land or in the sea, rocket stages can have a considerable environmental impact on the terrestrial ecosystem they affect. Upon crashing into the ocean, for instance, stages can break up into many small pieces, floating to the surface or sinking to the bottom.[30] Animals may be killed by the impact or consumption of the former rocket pieces.

More concerning, however is the dispersion of large amounts of unburned fuel on the surface of land or sea. Rocket tanks retain

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[23] Donna Lawler & Anthony Lloyd, ITechLaw, Legal Aspects of Launches and Satellite Operations, http://asia.itechlaw.org/assets/ITECHLAW/2-Anthony-Lloyd-and-Donna-Lawler.pdf.

[24] ISU Final Report, *supra* note 1, at 47.

[25] Ram Jakhu, General Principles of Space Law: Legal Status of Outer Space and Celestial Bodies, course lecture presentation at the McGill Institute of Air and Space Law (Oct. 6 2014).

[26] Virgin Galactic, www.virgingalactic.com (last visited Aug. 28, 2016).

[27] ISU Final Report, *supra* note 1 at 26.

[28] FRANCIS LYALL AND PAUL B LARSEN, SPACE LAW: A TREATISE 116 (2009).

[29] ISU Final Report, *supra* note 1, at 23.

[30] ICF Kaiser Consulting Group, FINAL ENVIRONMENTAL ASSESSMENT FOR THE SEA 31 (1999), *available at* https://fas.org/spp/guide/ukraine/launch/2_99Bslea.pdf (last visited Aug. 28, 2016).

approximately 9% of their propellant following detachment,[31] endangering both people and wildlife.[32] When this highly fuel comes back to Earth, it has the potential to spread over several kilometers, causing serious health problems for the local population and ecosystem.[33] Mitigation of payload separation harm currently takes the form of planned drop trajectories, but even these can deviate.[34]

2. Fuel Use

Another significant technical challenge to green launches is propellant input. Fuel use in today's industry is often synonymous with rocket choice and launch venue, as each particular rocket generally accepts its own mix of propellants, which vary greatly in environmental impact.[35] Whereas fuel choice is vital to future green launches, it is important to note that all current fuels are greatly detrimental to the local and atmospheric environments with which they interact.[36] Modern rocket propellants utilize highly toxic chemical compositions and contribute harmful gases into the atmospheric layers with which they interact.[37]

Although small on a global scale, a rise in rocket launch emissions could have deleterious consequences on the world's atmosphere.[38] In a recent study, climate scientists theorized that as few as one thousand yearly launches could lead to worldwide climate change.[39] Current negative effects of launch fuel include increasing levels of acid rain[40] and entrapment of black carbon in the upper reaches of the stratosphere.[41] Moreover, rockets deposit particulate matter directly into all layers of the Earth's atmosphere, from the

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[31] ISU Final Report, *supra* note 1.

[32] *Id.* at 3.

[33] Viikari, *supra* note 2, at 14.

[34] ISU Final Report, *supra* note 1, at 28.

[35] *Id.* at 31.

[36] A Sergeeva, "Analysis of the impact of rocket and space activities on the environment" (2004).

[37] Viikari, *supra* note 2, at 14.

[38] Kleiman, *supra* note 16, at 39.

[39] Adam Mann, Space Tourism to Accelerate Climate Change (Oct. 22, 2010), http://www.nature.com/news/2010/101022/full/news.2010.558.html (last visited Aug. 28, 2016).

[40] Viikari, *supra* note 2, at 14, 30.

[41] Jon Krois, *Onwards and Upwards: Space Tourism's Climate Costs and Solutions*, 37 COLUM. J. ENVTL. L. 40 (2011).

troposphere to the stratosphere.[42] The release of even trace amounts of ozone depleting and global warming inducing particulates has the potential to significantly modify global ozone levels in the coming years.[43]

Modern technology does not allow for harmless fuel use.[44] As such, "green propellants" are a general category of fuels that earn industry-leading scores in low toxicity, low pollution impact, and sustainable materials.[45] The most eco-friendly propellant in use today is a liquid-hydrogen/liquid-oxygen combination used by the US's Delta UV rockets and the European Ariane 5.[46] In contrast, the most polluting fuels in the industry is unsymmetrical dimethylhydrazine/nitrogen tetroxide, currently in use by Russia's Proton and China's Long March rockets.

The technical challenges underlying green fuel development are just as real as the economic and commercial challenges in the space industry, due to the high cost of rocket conversion. The greenest fuels can be retrofitted into current rocket models, but at a significant cost.[47] Moreover, new rocket designs and fuel combinations come with restrictively high insurance rates in their first launches, inhibiting proper technological development in a now private space industry.[48]

3. Launch Failure

Finally, the last significant technical challenge inhibiting environmentally-friendly space launches is launch success rate, and the environmental consequences that come about in a failed launch. Although launch success has greatly improved in the last decades, there still remains approximately a one in twenty risk[49] of launch

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[42] Kleiman, *supra* note 16, at 39.

[43] *Id.* at 41.

[44] However, there is research being done in the realm of alternate propulsion, in the form of solar-electric, magnetic levitation, and laser propulsion. ISU Final Report, *supra* note 1, at 16.

[45] *Id.*

[46] *Id.* at 9.

[47] ISU Final Report, *supra* note 1.

[48] *Id.*

[49] Launch success rates have improved steadily since the 1990s. The years between 1990-1999 saw a success rate of 92.8%, and 2000-2009 was 94.1% successful. *See*, SPACE LAUNCH REPORT, WORLDWIDE SPACE LAUNCH BOX SCORE (Dec. 4, 2014), http://www.spacelaunchreport.com/logyear.html.

failure, an average of over two failures per year. Upon failure, large quantities of unburned fuel are dispersed on the surface of the Earth and in the ocean, often in close proximity to the launch site.[50] Unlike in payload separation or regular propellant use, launch failures feature an extreme concentration of fuel in one specific ecosystem, exacerbating the injury and further prolonging Earth's natural recovery processes.

Launch failures are an inherent reality in the still nascent phase of human space exploration. What is more, launch failures have the potential to increase as further "green" technological developments are pushed on the industry.[51] The scientific uncertainty and risk accompanied with spaceflight are poignantly visible in launch failures, ranking among the most serious public concerns about space agencies, worldwide.[52]

In attempting to lessen the environment impact of space launches, there is the potential of making it (albeit hopefully temporarily) worse, a difficult political decision for space agencies and launch operators.

C. Space in General Environmental Law

General international environmental law is primarily governed by international treaties and principles of customary law. The underlying principles of sustainable development and environmental protection are said to have been first introduced at the 1972 UN Conference on the Human Environment (Stockholm Conference), where states recognized the importance of protecting the environment as the "desire of the peoples of the whole world and the duty of all governments."[53] It is important to note that the Stockholm Declaration was signed after the negotiations and deliberations leading to the 1967 Outer Space Treaty and the 1972 Liability

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[50] ISU Executive Summary, *supra* note 1.

[51] Viikari, *supra* note 2, at 44.

[52] ISU Final Report, *supra* note 1, at 61.

[53] UN Declaration of the United Nations Conference on the Human Environment, UN Doc A/CONF 48/14/Rev 1 (June 5-16, 1972) [hereinafter Stockholm Declaration]. *See also* Oscar Schachter, *The Emergence of International Environmental Law*, 44 J. Int'l Affairs 457 (1991).

Convention, thus underlining the lack of terrestrial environmental considerations in the latter treaties.[54]

The environmental movement as a whole has largely ignored space utilization.[55] No international agreements have specific space provisions, despite the increasing importance of the industry. However, three particular treaties are applicable and important to space launches, as presently formulated: (1) the 1979 Geneva Convention on Long-Range Transboundary Air Pollution (Air Pollution Convention), (2) the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol), and (3) the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol).[56] Moreover, soft and customary international law have an acknowledgeable effect on space in international law.

1. International Legislation

The Air Pollution Convention aims to reduce air pollution across international borders, with specific substances being of particular interest.[57] It is not yet clear if this agreement is applicable to space, as no formal complaint has been lodged with respect to transboundary air pollution caused by rocket launches.[58] However, the informative, collaborative, and consultative management of the treaty body has the potential to inform discussions on reduction of rocket pollution in a cross-boundary context. Yet, not all of the major space-faring nations have ratified the Convention. China, Japan, North Korea, South Korea, India, Israel, and Brazil are notably absent.

The Montreal Protocol calls for the reduction and eventual phasing-out of ozone-harmful substances.[59] Following up on the 1985 Vienna Convention for the Protection of the Ozone Layer, the two agreements call on states to "take appropriate measure… to

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[54] It has been argued that the environmental considerations in these treaties are strictly to safeguard human activity, and not for genuine environmental concerns: Viikari, *supra* note 2, at 285.

[55] *Id.* at 13.

[56] ISU Final Report, *supra* note 1, at 43.

[57] Some of these include aldrin, chlordane, and dieldrin, for instance.

[58] ISU Final Report, *supra* note 1.

[59] Montreal Protocol on Substances that Deplete the Ozone Layer, Sept. 16, 1987, 1522 UNTS 3 [hereinafter Montreal Protocol].

protect human health and the environment against adverse effects resulting … from human activities which modify… the ozone layer."[60] It is the most successful international environmental agreement ever, with all UN member states signing and ratifying the treaty.[61] Despite its successes, it has little practical effect on the space launch industry. Its definition of ozone depleting chemicals is currently too narrow to include halogenated ozone depleting chemicals, of which launch fuels form a part.[62] As such, the space launch sector is one of the only remaining industries that actively depletes the ozone layer, without commercial or regulatory incentives to change its behavior. [63]

The Kyoto Protocol's goal is to reduce greenhouse gas emissions by developed countries set percentage reduction targets and strong national implementation programs.[64] Kyoto has had mixed implementation results, with various countries making concerted efforts to reach their stated targets, others never signing (such as the United States), and still more withdrawing (notably, Canada). However, Kyoto was written to exclude international aviation and space activity.[65] As such, there is little incentive for launch operators to reduce their carbon emissions, given the lack of regulatory incentive, even in Kyoto-abiding states. With current climate change estimates proving worse than anticipated,[66] the lack of regulation in this area is worrisome, stated lightly.

2. Soft Law

The precautionary principle is an evolving principle of international environmental law. It encourages states to act in order to

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[60] Vienna Convention for the Protection of the Ozone Layer, Mar. 22 1985, 1513 UNTS 293 [entered into force 22 Sep 1988].

[61] United Nations Environmental Programme, Key Achievements of the Montreal Protocol to Date, http://www.unep.ch/ozone/Publications/MP_Key_Achievements-E.pdf (last visited Aug. 28, 2016).

[62] ISU Final Report, *supra* note 1, at 43.

[63] ID PH DIEDERIKS-VERSCHOOR & V KOPAL, AN INTRODUCTION TO SPACE LAW 131 (3d ed. 2008).

[64] Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 10 1997, UN Doc FCCC/CP/1997/7/Add 1, 37 I.L.M. 22 (1998) (entered into force 16 Feb 2005) [hereinafter Kyoto Protocol].

[65] ISU Final Report, *supra* note 1, at 43.

[66] Krois, *supra* note 41, at 41.

prevent environmental damage, even if there is still lingering scientific uncertainty on an issue.[67] The precautionary principle has been argued to be a principle of customary international law,[68] and forms an important part of numerous international environmental agreements and domestic environmental law frameworks.[69] It underlies the rationale for environmental assessments and impact statements, a common practice among launch states. The precautionary principle is ideally suited as a basis for environmental space legislation, due to its accord with the scientific uncertainties and risks that accompany space exploration.

Intergenerational equity is the implication that our legal framework should not work solely for the present, but should also take into account the interests of future generations.[70] The concept is common in global environmental regulation, as well as national environmental law, particularly in natural resource extraction, where trust funds are set up to account for the depletion of access to environmental goods for future generations.[71] Of notable example is Argentina's constitutional requirement that national space activities not "compromise the needs of future generations."[72] In space, the greed of the present generation risks compromising future opportunities for space exploration, which is as true in terrestrial space application as outer space regulation. The lacuna in this area is a notable void in regulation.

3. Domestic Environmental Law

Note: This topic is further discussed in the following subsection "Environmental Protection of Space Law." Due to the diversity of legal regimes governing space in domestic environmental law, the subject cuts across both topics, and as such, is discussed briefly in each instance, in an effort to offer a cogent whole.

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[67] European Union, *The Precautionary Principle* (2005).

[68] Hobe, *supra* note 13.

[69] ISU Final Report, *supra* note 1, at 50.

[70] Edith B. Weiss, *Intergenerational Equity: A Legal Framework for Global Environmental Change*, *in* ENVIRONMENTAL CHANGE AND ENVIRONMENTAL LAW: NEW CHALLENGE AND DIMENSIONS 395 (Edith B. Weiss ed., 1992).

[71] *Id.* at 155-156.

[72] JULIAN HERMIDA, LEGAL BASIS FOR A NATIONAL SPACE LEGISLATION 193 (2004).

National environmental policy takes different forms across the world. From constitutional protections,[73] to legislative requirements, to regulatory frameworks, states implement environmental protection in distinct ways. However, one common theme cuts across the spectrum: the domestic requirement for environmental impact assessments and statements (EIAs) for space launch activities.[74]

EIAs are not required in international environmental law.[75] However, when implemented, they rest on the ideology of sustainable development[76] and the precautionary principle,[77] common themes in international environmental legislation. EIAs, broadly, are a procedure to evaluate the likely impact of a proposed activity on the environment. In the case of space launches, particular elements are taken into consideration, such as pollution control, environmental protection measures, reporting, post-project analysis, and site rehabilitation.[78] EIAs require public participation, which can be complicated, expensive, and slow.[79]

Across jurisdictions, EIAs can be mandated in a variety of fashions. US-based space launches must perform EIAs through the Federal Aviation Administration in compliance with the National Environmental Protection Act.[80] Russian space launches, both in Russia and Kazakhstan, must perform EIAs in compliance with the Russian Statute on Licensing Space Operations.[81] European space launches must accept inspections from the European Space Agency's (ESA) Coordinating Office on Sustainable Development.[82] Chinese launches must conform to the People's Republic of China Environmental Protection Law.[83]

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[73] *Id.*

[74] Viikari, *supra* note 2, at 261.

[75] ISU Final Report, *supra* note 1, at 43.

[76] Stockholm Declaration, *supra* note 53.

[77] PATRICIA W BIRNIE & ALAN E BOYLE, INTERNATIONAL LAW & THE ENVIRONMENT (2002).

[78] Viikari, *supra* note 2, at 269.

[79] *Id.* at 271.

[80] National Environmental Policy Act of 1969, Pub. L. 91-190, 83 Stat. 852 (1970).

[81] Viikari, *supra* note 2, at 275.

[82] ISU Final Report, *supra* note 1.

[83] *Id.* at note 1 at 51.

The difficulty in regulating EIAs comes back to the concept of a "race to the bottom", as presented in the research rationale.[84] As the core of national environmental legislation varies from state to state, the rigor and efficacy by which EIAs are implemented varies widely.[85] Given this disparity, the launch industry may be inclined to do business where regulation is least stringent, and thus, most attractive.[86]

D. Environmental Protection in Space Law

Current international space law is a patchwork of international treaties, bilateral agreements, customary international law, and sometimes, official resolutions and declarations. International space law is often completed with national and local space legislation and regulations.

For concision, this paper's analysis will focus on the provisions affecting green launching existent in the most notable and influential international space law treaties, notably the Outer Space Treaty, the Liability Convention, and the Registration Convention.

1. International Treaties

International space law has historically has little to say about environmental issues.[87] Where international agreements include environmental provisions, the goal has been to assign state responsibility[88] and mitigate harm from human or mechanical failure.[89] International space law has taken few proactive steps to prevent terrestrial environmental degradation resulting from space launches.

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[84] See "Research Rationale," above.

[85] Hermida, *supra* note 72, at 173.

[86] Cologne University, *Project 2001 Working Group on National Space Legislation,* Institute of Air and Space Law.

[87] ML Chen, *Development of Environmentally Acceptable Propellants*, PROCEEDING OF THE 84TH SYMPOSIUM OF THE PROPULSION AND ENERGETIC PANEL ON THE ENVIRONMENTAL ASPECTS OF ROCKET AND GUN PROPULSION 305 (1994).

[88] Liability Convention, supra note 8.

[89] *Id.*; *See also* Krois, *supra* note 41, at 41.

Outer Space Treaty

Where space law has succeeded is the imposition of continuous supervision on states for their actions in space.[90] The framework of international space law in this regard—holding all states accountable for injuries to others in space exploration—has proven to be a groundbreaking development in environmental responsibility, which other common protection regimes, such as fishing or air pollution, cannot match. However, the Outer Space Treaty, and its accompanying Liability and Registration Conventions, lack comprehensive plans for terrestrial environmental preservation and control of externalities in the exploitation of space.[91]

Even the Outer Space Treaty's infamous Article IX, mandating "due regard" for other state parties and calling for "cooperation and mutual assistance" in space exploration, has little practical terrestrial use.[92] The requirement to avoid "harmful interference" has never been applied in the context of environmental preservation from launching, as the harmful interference envisaged is that of human activity in space, and not human and environmental well being on Earth.[93] Resulting, the Outer Space Treaty has little practical application for safeguarding green launching provisions into the future.

Article X of the Outer Space Treaty allows third party states to observe the launch and flight of a state object.[94] This provision is generally a positive development for environmental protection, as it allows third party states to be ready to respond in case of a failed launch or unexpected payload separation. Working in concert with Article 5 of the Rescue & Return Agreement, third party states are under a duty to notify the launching state of any harm to their territory[95] and resulting, the launching authority must eliminate any possible danger of harm.[96] Combining the aspects of the Outer

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[90] Outer Space Treaty, *supra* note 5, at arts VI & VII.

[91] Krois, *supra* note 41, at 45.

[92] Outer Space Treaty, *supra* note 5, at art IX.

[93] Viikari, *supra* note 2, at 285.

[94] Outer Space Treaty, *supra* note 5, at art X.

[95] Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, *opened for signature* Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119 [hereinafter Rescue and Return Agreement].

[96] *Id.*, at art V(4).

Space Treaty and Rescue & Return Agreement in this regard, environmental protection during space launches is bettered as a result.

Moreover, Article III of the Outer Space Treaty calls for parties to carry on "activities in the exploration and use of outer space… in accordance with international law.[97] Whereas on its face this provision seems well worded to protect against environmental launch harms, one will remember that space activities are exempt from nearly all successful formal international environmental legal mechanisms, such as the Air Pollution Convention, the Montreal Protocol, and the Kyoto Protocol.[98] Whereas Art III of the OST has the potential to hold states accountable for launch activities, it loses its effectiveness in the legal carve-outs designed for space activities.

Liability Convention

Of international space laws, the Liability Convention (LC) is the most appropriate mechanism through which to mitigate and control environmental damage resulting from space launches. Art II of the Liability Convention imposes absolute liability to damage caused by space objects on the surface of the Earth. Its provisions have been activated twice, but never in claims against launch activities.[99] However, this provision, and the Convention as a whole, are positive developments in international space law, significant improvements from the early days of launching, when spent boosters, cones, and explosive bolts were simply abandoned.[100]

Article V of the Liability Convention calls for joint and several liability between launching states.[101] This legislative requirement has been important to assure reparation in the case of environmental harm from launch failure or payload damage. However, its environmental efficacy is consistently undermined through the signing of cross waivers of liability and exclusion of liability contracts, wherein one state shoulders all the blame for environmental damage that may occur following a launch.[102] Although politically and

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[97] Outer Space Treaty, *supra* note 5, at art III.
[98] Montreal Protocol, *supra* note 59.
[99] LYALL & LARSEN, *supra* note 28 at 118.
[100] *Id.* at 303.
[101] Liability Convention, *supra* note 8, at art V.
[102] LYALL & LARSEN, *supra* note 28, at 284.

legally efficient, these agreements remove environmental burdens from states, thereby reducing precaution in launch activities.[103]

Article XII of the Liability Convention calls for payment to be made according to "international law and the principles of justice and equity" in order to provide reparation for damage.[104] This provision, along with the methods established for proceeding with a claim in Article VIII,[105] are generally good practices in environmental law, establishing clear guidelines for compensation in cases of harm. As a counter argument, the provision lacks penal enforcement. States can thus put a "price" on their environmental costs, as has been done by Russia in the case of the Baikonur Cosmodome, located in Kazakh territory.[106]

Lastly, Article VII of the Liability Convention provides one of space law's most controversial environmental provisions, clearing a state of international liability towards its own citizens.[107] Although not surprising,[108]Article VII shows the inability of space law—thus far—to incorporate fundamental notions of environmental human rights into its legal framework. These lack of domestic legal protections have the potential to produce launch sites of convenience in a growing industry, given lower regulatory and launch costs associated with loose domestic protectionist frameworks.[109]

2. Environment in National Space Law

Space is regulated in a variety in variety of different manners on a domestic level. Certain countries, such as the US, Russia, Australia, the UK, Ukraine, Sweden, South Africa, and Japan have comprehensive space-specific laws. [110] Other states employ executive policy to implement their space programs.[111] Still more regulate space as part of their general legal framework, notably France

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[103] Viikari, *supra* note 2, at 169.

[104] Liability Convention, supra note 8, at art XII.

[105] *Id.*, at art VIII

[106] LYALL & LARSEN, *supra* note 28, at 46 (a secret settlement was reached between Russia and Kazakhstan).

[107] Liability Convention, supra note 8, at art VII.

[108] ODUNTAN, *supra* note 12 (establishing domestic liability would violate state sovereignty).

[109] *Id.* at 75.

[110] Hermida, *supra* note 72, at 73.

[111] *Id.* (Norway, Brazil, and Italy are among these).

and Canada.[112] One common denominator remains, however: all space-faring states have implemented authorization systems to ensure that no activities entail significant safety perils, as required in international space law.[113]

Yet there exist no international requirements for shaping domestic space law with regards to environmental protections during space launches. Whereas international environmental law helps shape domestic systems in the areas of safety and liability for harmful contamination of Earth,[114] these concerns—as previously expressed—are primarily protections against tortious damage designed to safeguard human and national interests, leaving environmental protection as solely a side benefit.

Of notable example are launch failures or payload separation that occur on one's one territory.[115] Under international space law, the state is under no duty to compensate its citizens for damage suffered as a result. Had this damage occurred over an international broader, however, the state would be liable for damage.[116]

Although there exists a relative wealth of jurisprudence related to space launches,[117] little case law deals practically with environmental damage. Of notable exception is the dual cases *Florida Coalition for Peace & Justice v George HW Bush*.[118] These two cases, heard in 1989 and 1990, involved two separate launches from Florida's Cape Canaveral. It was alleged that NASA had failed to satisfy all of the requirements of the National Environmental Policy Act (NEPA) in assessing the risk of launching nuclear power into space. The court found in Bush's favor, granting discretion to NASA's "reasoned evaluation of relevant factors" in deciding that it had met all necessary NEPA requirements.[119] *Florida Coalition* is crucial domestic case law in the US context for granting discretion to federal

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[112] *Id.* at 74.

[113] *Id.* at 75.

[114] *Id.*

[115] Liability Convention, supra note 8, at art VII.

[116] *Id.*, at art II.

[117] *See, e.g.*, European Center for Space Law, Feature: Space Law Cases, http://www.esa.int/SPECIALS/ECSL/SEMT9MMKPZD_0.html (last visited Aug. 28, 2016).

[118] Florida Coalition for Peace and Justice v. George Herbert Walker Bush, Civil Action No 89-2682-OG DDC (1989); Florida Coalition for Peace and Justice v. George Herbert Walker Bush, Civil Action No 89-2682-Og DDC (1990).

[119] DIEDERIKS-VERSCHOOR & KOPAL, *supra* note 63, at 154.