AVOIDING MOONRAKER: AVERTING UNILATERAL GEOENGINEERING EFFORTS

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"But the Agreement," Mary said, sitting down on her chair and focusing on her colleague's voice. "You know what it says. No atmospheric interventions without consultation and agreement."

"We are breaking the Agreement," Chandra said flatly.

—Kim Stanley Robinson[1]

ABSTRACT

Geoengineering has gradually moved from the realm of forbidden technology to a real possibility for addressing the increasingly devastating effects of climate change. Despite many concerns regarding the effects of geoengineering on the planet as a whole, absent drastic action from the global community to reduce emissions, which does not currently seem likely, its deployment seems inevitable in the near future.

This Article focuses on solar radiation management (SRM), particularly on upper atmosphere and space-based mechanisms.

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1 KIM STANLEY ROBINSON, THE MINISTRY FOR THE FUTURE: A NOVEL 19 (2020).

There are four main risks that must be evaluated in this area: (1) the risk of geoengineering; (2) the risk of unilateral state action; (3) the risk of unilateral private action; and (4) the risk of doing nothing. The Article posits that our legal system is poorly designed for addressing these risks, since it focuses on *ex post* actions rather than providing *ex ante* measures to adequately evaluate and minimize the risks. Unilateral actions by individual states or by private actors cannot be adequately addressed by *ex post* legal measures, such as liability regimes. There is a need for robust regulatory mechanisms at an international level to mitigate the negative consequences that unilateral action would inevitably give rise to. Even with such regulatory mechanisms, however, the significance of the harm caused by global temperature increases is such that it may outweigh any potential negative consequences to states who are faced with the choice between the survival of their people or adherence to international legal standards.

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I. INTRODUCTION

In June 2021, researchers from Harvard University's SCoPEx (Stratospheric Controlled Perturbation Experiment) were scheduled to launch a balloon above Sweden that would have released a small amount of material to test the efficacy and risks of solar radiation management (SRM) as a means of changing the climate.[2] In March 2021, the launch was delayed to 2022 after a recommendation from the SCoPEx advisory committee[3] in response to concerns raised by the indigenous Sámi people in Sweden. Opponents[4] of this project are concerned that it will violate an international moratorium on geoengineering, particularly if it leads to further, larger scale experiments, and that it could encourage the continued use of fossil fuels without risk of climate catastrophe.[5] Skeptics were quick to point out the similarity between the mechanisms of the experiment and the plot of the 2013 dystopian film by Bong Joon-Ho, *Snowpiercer*.[6] Indeed, geoengineering, or climate engineering, as it is also known, seems straight out of the realm of science fiction. We are, however, coming closer to it becoming a reality at the same time that we are at a crossroads where lack of action from governments combined with the growing threat and effects of climate change are putting billions of lives at risk.

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2 *ScoPEx: Stratospheric Controlled Perturbation Experiment*, KEUTSCH GRP. AT HARVARD, https://www.keutschgroup.com/scopex [https://perma.cc/Z5L2-RG94].

3 James Temple, *Geoengineering researchers have halted plans for a balloon launch in Sweden*, MIT TECH. REV. (Mar. 31, 2021), https://www.technologyreview.com/2021/03/31/1021479/harvard-geoengineering-balloon-experiment-sweden-suspended-climate-change/ [https://perma.cc/98JE-3CU2].

4 Haley Dunleavy, *An Indigenous Group's Objection to Geoengineering Spurs a Debate About Social Justice in Climate Science*, INSIDE CLIMATE NEWS (July 7, 2021), https://insideclimatenews.org/news/07072021/sami-sweden-objection-geoengineering-justice-climate-science/[https://perma.cc/ZJ57-G6TW].

5 Alister Doyle, *Planned Harvard balloon test in Sweden stirs solar geoengineering unease*, REUTERS (Dec. 18, 2020, 10:04 AM), https://www.reuters.com/article/us-climate-change-geoengineering-trfn/planned-harvard-balloon-test-in-sweden-stirs-solar-geoengineering-unease-idUSKBN28S232 [https://perma.cc/7XZ3-EFMX].

6 Spencer Buell, *Sure Hope this Snowpiercer-Esque Harvard Project Doesn't End Up like the Movie*, BOSTON MAG. (Jan. 22, 2021, 4:21 PM), https://www.bostonmagazine.com/news/2021/01/22/snowpiercer-harvard-scopex/ [https://perma.cc/S34G-2KWN].

Despite concerns regarding the potential dystopian effects of geoengineering, it is increasingly possible that sometime in the near future, geoengineering mechanisms will be deployed. Understanding the legal landscape governing geoengineering is therefore imperative in order to minimize the chance of a *Snowpiercer*-like situation from arising. Furthermore, conceptualizing how law may be limited in addressing issues relating to the deployment of geoengineering, particularly with respect to the relation between risk and law, offers a (perhaps pessimistic) understanding of how our future is likely to unfold. This Article argues that it is too late to advocate for a moratorium on geoengineering, and that we must come to terms with the inevitability of the eventual deployment of geoengineering mechanisms to combat climate change.[7] Regulatory regimes can only do so much to deter states from taking action, particularly when faced with a choice between the survival of their people and adherence to external imposed legal standards.

The threat posed by climate change has been well-documented and acknowledged by scientists and lawmakers for decades. In the nearly thirty years since the United Nations Framework Convention on Climate Change (UNFCCC) was established,[8] the international community has struggled to take the necessary steps to reduce the impact of climate change. Disagreement over the allocation of responsibility, climate skepticism, and concerns that climate change mitigation measures would hamper economic development have overshadowed the existential crisis posed by climate change.[9] International environmental agreements have been unambitious in setting targets for climate mitigation, yet neither the UNFCCC nor the 1997 Kyoto Protocol mentioned climate adaptation.[10] This

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7 The increasing inevitability of geoengineering can be seen in the changing tone of articles by legal academics and policymakers over the past decade, from a conceptualization of geoengineering as a remote policy to an acknowledgment that some form of geoengineering is likely to be used in the near future.

8 United Nations Framework Convention on Climate Change art. 2, May 9, 1992, 1771 U.N.T.S. 107 [hereinafter UNFCCC], https://unfccc.int/resource/docs/convkp/conveng.pdf [https://perma.cc/4RU2-PKL3].

9 *See* Antonia Eliason, *Using the WTO to Facilitate the Paris Agreement: A Tripartite Approach*, 52 VAND. J. TRANSNT'L L. 545, 575 (discussing some of the issues relating to sustainable development).

10 *See What do adaptation to climate change and climate resilience mean?*, UNFCCC, https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

reluctance to acknowledge that our collective failings will require us to live with the effects of climate change has in part been motivated by a desire to ensure that we primarily try to mitigate the effects of climate change. The 2016 Paris Agreement marked the first time that a multilateral international environmental convention acknowledged climate adaptation in addition to climate mitigation.[11]

Climate mitigation and climate adaptation are the two primary branches of climate change management. The third branch of climate change management, geoengineering, has yet to be addressed by any international legal agreements. Geoengineering is most commonly defined as "the deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming."[12] The uncertainty of geoengineering stems from the potentially Earth-destroying unintended consequences of such mechanisms. Even more than with climate adaptation, there is also the concern that reliance on geoengineering would divert attention from the much more pressing need to take significant measures to reduce our greenhouse gas (GHG) emissions and thus mitigate the effects of climate change. As temperatures continue to rise, however, and the possibility of staying below the 2C° temperature increase provided for in the Paris Agreement seems increasingly remote, attention is steadily turning to geoengineering.[13]

While there are a number of different types of geoengineering mechanisms, this Article focuses on space-based geoengineering and the security threats that it poses. There are four primary areas of risk examined here: (1) the risk of the geoengineering mechanisms themselves; (2) the risk of unilateral state action; (3) the

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[https://perma.cc/M7J7-LTZT] (highlighting the UNFCCC's definition of climate adaptation as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. . . . [and] refer[ring] to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change").

[11] *See* Paris Agreement art. 7 § 1, Dec. 12, 2015, T.I.A.S. No. 16-1104 ("Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2.").

[12] THE ROYAL SOC'Y, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY ix, 1 (2009).

[13] Fred Pearce, *Geoengineer the Planet? More Scientists Now Say It Must Be an Option*, YALE ENV'T 360 (May 29, 2019), https://e360.yale.edu/features/geoengineer-the-planet-more-scientists-now-say-it-must-be-an-option [https://perma.cc/ZU49-BXLS].

risk of unilateral private action; and (4) the risk of doing nothing. The Article first provides an overview of SRM and the various types of mechanisms covered under that umbrella. In Section II, the Article turns to look at the applicable legal regime, providing a broad overview of some of the key areas that may impact the regulation of geoengineering. In Section III, the Article examines each of the different categories of risk and highlights areas in which the legal regime falls short, arguing that the *ex post* nature of most legal solutions prevents meaningful *ex ante* action from being taken. Finally, the Article offers some suggestions for how to remedy the gaps in the existing legal regime.

II. SOLAR RADIATION MANAGEMENT: AN OVERVIEW

Geoengineering falls into two main categories: carbon dioxide removal (CDR) and solar radiation management (SRM).[14] As this Article focuses on space-based geoengineering mechanisms, CDR mechanisms, which include large-scale afforestation, carbon capture and storage, and ocean fertilization, are outside its scope. Solar radiation management (SRM) includes "increasing surface and cloud albedo, the methods of injecting stratospheric aerosols and installing space reflectors."[15] SRM as a means of redressing climate change poses enormous risks to the world's population. While much of the required technology is currently speculative in nature, rapid technological advances and the growing recognition of the crisis posed by climate change may mean that some of the SRM mechanisms will be available for use in the near future. Certain types of SRM are also relatively low-cost, making them accessible to

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[14] Gerd Winter, *Climate Engineering and International Law: Final Exit or the End of Humanity?*, *in* CLIMATE CHANGE: INTERNATIONAL LAW AND GLOBAL GOVERNANCE, VOLUME I: LEGAL RESPONSES AND GLOBAL RESPONSIBILITY 979, 981 (Oliver C. Ruppel, Christian Roschmann & Katharina Ruppel-Schlichting eds., 2013).

[15] *Id.* at 982 ("Large scale afforestation, BECS, biochar, enhanced weathering, CO_2 air capture, ocean fertilisation and CCS are all described as Carbon Dioxide Removal (CDR), whereas increasing surface and cloud albedo, the methods of injecting stratospheric aerosols and installing space reflectors are known as Solar Radiation Management (SRM)"). Albedo is defined as "the fraction of incident radiation (such as light) that is reflected by a surface or body (such as the moon or a cloud)." *albedo*, MERRIAM-WEBSTER, https://www.merriam-webster.com/dictionary/albedo [https://perma.cc/4XK2-2YNR].

many actors, whether at the private or at the state level.[16] SRM mechanisms also have the potential to reduce temperatures more rapidly than CDR mechanisms,[17] increasing their attractiveness as our climate situation becomes direr.

The primary concern relates to the irreversibility of SRM and the consequent potential for planetary destruction that it raises. Additionally, SRM gives rise to two types of moral hazard: first, that countries could reduce efforts to mitigate climate change effects in reliance on the possibilities of SRM; and second, that failure to research geoengineering methods could lead to deployment of insufficiently researched SRM mechanisms.[18] This becomes particularly salient when we account for the disparities in the technological capabilities of different nations, and the possibility that Global North countries "might collaborate to pursue, over the objections of poorer nations, stratospheric aerosol injection, even though doing so could foreseeably result in disruption of the monsoon relied upon by India, Bangladesh, and other nations for agricultural productivity,"[19] to give but one example of potential consequences.

SRM mechanisms stand in contrast to the generally less controversial CDR mechanisms, which include reforestation and afforestation, and various carbon dioxide capture mechanisms. This Article focuses primarily on stratospheric aerosols and space-based reflectors, but understanding the range of mechanisms is helpful in understanding the scope of the controversy. Key to SRM is that none of these proposed techniques would reduce GHG emissions.[20] SRM also cannot compensate for such climate damage as ocean acidification, and the maximum cooling potential is unclear.[21]

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16 Andrew Lockley, Gideon Futerman & D'Maris Coffman, *Geoengineering and Public Trust Doctrine*, 14 CCLR 85, 93 (2020).

17 Albert C. Lin, *Avoiding Lock-In of Solar Geoengineering*, 47 N. KY. L. REV. 139, 141 (2020).

18 Michael Burger & Justin Gundlach, *Research Governance*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 269, 278 (Michael B. Gerrard & Tracy Hester eds., 2018); *see also* NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH 152 (2015).

19 Burger & Gundlach, *supra* note 18, at 278.

20 NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 1.

21 Douglas G. MacMartin, Katharine L. Ricke & David W. Keith, *Solar Geoengineering as Part of an Overall Strategy for Meeting the 1.5°C Paris Target*, 376 PHIL. TRANSACTIONS ROYAL SOC'Y A., Apr. 2, 2018, at 1, 2.

a. Increasing Surface Albedo

Increasing surface albedo is the least controversial SRM mechanism, since it involves simple, reversible actions like painting roofs of buildings white to reflect more light, planting higher albedo crops, covering desert surfaces with reflective materials, or floating reflective microbubbles on just under the ocean surface to increase ocean reflectivity.[22] One of the main challenges of these methods would be the scale of the deployment required to have substantive effects on climate.[23] Placing reflective materials across large swathes of land would prevent alternative uses for the land, including use for producing food crops or for afforestation that would sequester carbon more efficiently.[24] On a small scale, however, increasing surface albedo could be effective in temporarily reducing temperatures in cities, staving off the worst effects of increasingly hot summer days.

b. Cloud Brightening

Cloud brightening envisions "increasing the concentration of cloud-condensation nuclei in the lower atmosphere, particularly over ocean areas, thereby whitening clouds with the aim of increasing the reflection of solar radiation."[25] Cloud brightening would involve ground-based or lower atmosphere-based efforts, with current models envisioning spraying seawater into the air to increase cloud reflectivity.[26] This would in turn attract water droplets, which would create "clouds with smaller drops but more of them" that would consequently be fluffier and have a more

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22 NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 128-29.

23 Phillip Williams et al., *Impacts of Climate-Related Geoengineering on Biological Diversity*, *in* GEOENGINEERING IN RELATION TO THE CONVENTION ON BIOLOGICAL DIVERSITY: TECHNICAL AND REGULATORY MATTERS 5, 11 (Secretariat of the Convention on Biological Diversity ed., 2012).

24 *Id.* at 74.

25 *Id.* at 8.

26 Michael B. Gerrard, *Introduction and Overview*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 1, 2 (Michael B. Gerrard & Tracy Hester eds., 2018).

reflective surface area.[27] The drawback of this technique is that once commenced, it would need to be continued indefinitely since halting its use could result in rapid warming.[28] This gives rise to what is known as the "termination problem," whereby a sudden end to the SRM mechanism would quickly result in the climate reverting to its ungeoengineered state.[29] As discussed below, this is a key concern with most of the SRM mechanisms.

c. Stratospheric Aerosols

Stratospheric aerosols would involve injecting particles, particularly sulfates, into the upper atmosphere with the goal of increasing the reflection of sunlight back into space.[30] The Catch-22 of using stratospheric aerosols is that they could simultaneous deplete stratospheric ozone while also blocking UV rays, leaving the net effect uncertain.[31] Furthermore, as with cloud brightening, once commenced, without a significant decrease in GHG emissions, the use of stratospheric aerosols would need to be continued to prevent global warming from resuming at a much faster than current rate.[32]

While potential positives include an increase in plant photosynthesis, since the sky would become brighter (estimates range from three to five times brighter), the model is based on replicating the effect of large volcanic eruptions and the subsequent cooling that results from the sulfurous particles that are dissipated throughout the upper atmosphere, which is empirically untested.[33] The most cited example is the 1991 Mount Pinatubo event, which has provided researchers with much of the observable data on these kinds of phenomena.[34]

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27 Eli Kintisch, *Technologies*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 28, 34 (Michael B. Gerrard & Tracy Hester eds., 2018).

28 *Id.* at 36.

29 Albert C. Lin, *The Missing Pieces of Geoengineering Research Governance*, 100 MINN. L. REV. 2509, 2568 (2016).

30 Williams et al., *supra* note 23, at 8.

31 Jesse L. Reynolds, *International Law*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 57, 71 (Michael B. Gerrard & Tracy Hester eds., 2018).

32 Kintisch, *supra* note 27, at 33.

33 Kintisch, *supra* note 27, at 29, 32.

34 NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 72; *see also* Williams et al., *supra* note 23, at 50.

Stratospheric aerosols have a relatively short lifetime, and consequently the termination problem is significant. Abrupt termination would potentially result in a rapid increase in global temperature.[35] As will be discussed later, this risk requires that there be clear mechanisms in place to address the governance of geoengineering efforts during and after the deployment of stratospheric aerosols.

d. Space-Based Reflectors

Although technologically the furthest off, space-based SRM methods offer some of the more theoretically fascinating options to reduce the effects of climate change. Possible techniques include launching solar sunshades into Earth orbit, which would require a careful balancing of weight and costs, as heavier sunshades are more expensive to launch, while lighter ones are more vulnerable to being disrupted.[36] An even more speculative proposal would involve launching a ring of sunshades near the LaGrange 1 point, which is one of five points where the Earth maintains the same position with respect to the Sun.[37] This proposal would require launching ten trillion small disks, which would amount to one million disks launching every second for thirty years from the Earth's surface.[38] Due to the hypothetical nature of most of the proposed space-based SRM mechanisms, there has been less discussion of their risks in the available literature. There is merit in examining these risks, however, since what appears technological distant today may very well be a practical reality tomorrow.

With all of the SRM mechanisms, other than land-based mechanisms to increase surface albedo, the big worry is the termination problem, wherein ceasing to deploy such mechanisms will result in a significant accelerated temperature rise.[39] It has been noted that the greater the magnitude of the SRM used in relation to albedo modification, the greater the risk of severe impacts of abrupt

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[35] Lockley, Guterman & Coffman, *supra* note 16, at 86.

[36] Kintisch, *supra* note 27, at 33.

[37] Kintisch, *supra* note 27, at 33.

[38] Kintisch, *supra* note 27, at 33.

[39] Burger & Gundlach, *supra* note 18, at 279; *see also* NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 63.

termination.[40] The risk is magnified where CO_2 emissions continue to rise during the time the SRM is deployed, and where that increase is countered by increasing the amount of albedo modification.[41] Related to the termination effect is the risk of technological lock-in, whereby once SRM mechanisms are deployed, there can be no variation from the technology initially chosen, due to the rapid warming that would result from sudden withdrawal of the initial mechanism.[42] These risks will be discussed further below.

III. APPLICABLE LEGAL REGIME

As geoengineering is a rapidly developing field and one that has been the source of much controversy and debate, much has been written elsewhere about the patchwork legal regime that applies to geoengineering generally.[43] The discussion here focuses only on those instruments most relevant to SRM mechanisms, particularly stratospheric aerosol injections and space-based reflectors. As a preliminary matter, the section provides an overview of the legal delineation between sovereign air space and outer space, before turning to the different categories of *lex specialis* applicable to geoengineering, and then concluding with a brief look at general public international law.

a. Delineation Between Sovereign Air Space and Outer Space

The legal regime that applies to outer space is a robust, treaty-based area of *lex specialis*. With aerial SRM mechanisms ranging

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40 NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 65.

41 NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 65.

42 DEBORAH GORDON, SMRITI KUMBLE & DAVID LIVINGSTON, ADVANCING PUBLIC CLIMATE ENGINEERING DISCLOSURE 2 (2018).

43 *See, e.g.*, Ralph Bodle, *Geoengineering and International Law: The Search for Common Legal Ground*, 46 TULSA L. REV. 305 (2010); Winter, *supra* note 14; Gerrard, *supra* note 26; Reynolds, *supra* note 31; Ralph Bodle et al., *The Regulatory Framework for Climate-Related Geoengineering in Relation to the Convention on Biological Diversity, in* GEOENGINEERING IN RELATION TO THE CONVENTION ON BIOLOGICAL DIVERSITY: TECHNICAL AND REGULATORY MATTERS 99 (2012); William C.G. Burns, *Climate Geoengineering, Solar Radiation Management and Its Implications for Intergenerational Equity*, 4 STAN. J.L. SCI. & POL'Y 37 (2011); Jesse L. Reynolds, *Solar Geoengineering to Reduce Climate Change: A Review of Governance Proposals*, 475 PROC. R. SOC. A., Sept. 4, 2019, at 1.

from cloud-brightening to space-based reflectors, the question is what constitutes outer space for purposes of international law.

Space-based reflectors are the most speculative of the SRM mechanisms, and are also the most clearly space-based of these geoengineering techniques. Deploying reflectors at a LaGrange point is unquestionably outer-space based. Where stratospheric aerosols or methods by which surface and cloud albedo are increased are envisaged, however, the question of what constitutes outer space comes into play. The Outer Space Treaty does not define where the sovereign air space of a state ends and international commons of outer space begins, although this is commonly assumed to be around 100 km above the Earth,[44] at what is known as the Kármán Line.[45] Certain countries, including Australia, Denmark and Kazakhstan, have adopted the view that airspace ends at 100km above sea level, taking a spacial approach.[46] At this distance from Earth, the more speculative possibility of space reflectors is the only SRM mechanism that would exist.

In the absence of a standard definition for where outer space begins, some countries have taken a functionalist approach to its delimitation, which suggests that the distinction between air space and outer space should be made based on the objectives and missions being carried out.[47] The United States has taken a third approach and has deliberately refused to draw any conclusions, remaining agnostic and noting that there is no need to provide a clear definition at this point.[48] These different position on the delineation between sovereign air space and outer space reflect the underlying question of whether the Kármán Line is in fact a reality. The validity of the Kármán Line as a delineator has been challenged by Thomas Gangale, who posits that it may have arisen as a

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44 Winter, *supra* note 14, at 985.

45 Jonathan C. McDowell, *The Edge of Space: Revisiting the Karman Line*, 151 ACTA ASTRONAUTICA 668, 669 (2018). The Kármán line marks the point at the which the atmosphere becomes too thin to support aeronautical flight. While commonly set at 100 km, there are arguments that it could be lower, for instance at 80 km. *Id.* at 668.

46 Timothy G. Nelson, *Where does space begin? The decades-long legal mission to find the border between air and space*, SPACENEWS (Mar. 26, 2019), https://spacenews.com/op-ed-where-does-space-begin-the-decades-long-legal-mission-to-find-the-border-between-air-and-space/ [https://perma.cc/T2YW-TZA3].

47 Michael Byers & Andrew Simon-Butler, *Outer Space*, *in* THE MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW (2020).

48 *Id.*

misunderstanding between Andrew G. Haley, who coined the term, and von Kármán himself.[49]

Closer to Earth, one of the proposed methods to disperse stratospheric aerosols would involve the use of high-altitude platforms, at a distance of 20+km from the planet's surface.[50] High-altitude platforms consist of aircraft, whether airplanes, balloons or airships, usually unmanned, that operate at an elevation above 20km from the surface in the stratosphere with a view to conducting remote sensing operations or providing telecommunications networks.[51] These could also be used for dispersing stratospheric aerosols, although as with other SRM technology, this is currently experimental in nature. Applying a functionalist approach to outer space, it could be argued that the nature of the activity conducted from such high-altitude platforms could constitute activities in near-space, which has been posited as existing between sovereign air space and outer space. It also suggests that a need for a clearer definition on the delimitation of outer space may arise in the near future.

For purposes of the following legal analysis, stratospheric aerosol injections are viewed as falling under state sovereignty, while space-based reflectors are within the jurisdiction of laws pertaining to outer space.

b. International Environmental Law

While all climate change measures fall broadly under the UN Framework Convention for Climate Change, the 1992 Convention does not explicitly provide for geoengineering.[52] Enshrined in the UNFCCC is the precautionary principle, with Article 3.3 stating that "[w]here there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing

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49 *See* Thomas Gangale, *The Non-Kármán Line: An Urban Legend of the Space Age*, 41 J. SPACE L. 151, 171 (2017).

50 *See, e.g.*, Wake Smith & Gernot Wagner, *Stratospheric Aerosol Injection Tactics and Costs in the First 15 Years of Deployment*, 13 ENV'T RSCH. LETTERS, Nov. 23, 2018, at 1, 3 (noting that "[h]igh payload, high altitude aerostats have been hypothesized but not yet successfully tested, and in all events, are operationally fragile . . . .").

51 *See* Flavio Araripe d'Oliveira, Francisco Cristovão Lourenço de Melo & Tessaleno Campos Devezas, *High-Altitude Platforms—Present Situation and Technology Trends*, 8 J. AEROSPACE TECH. MGMT. 249, 249 (2016).

52 UNFCCC, *supra* note 8.

such measures[.]"[53] Although this might suggest that geoengineering should be pursued as a way to prevent threats of serious or irreversible damage caused by climate change, the focus of the UNFCCC and its application of the precautionary principle has been on climate change mitigation.[54] The Paris Agreement, while explicitly addressing climate change adaptation, marking a shift from the mitigation-focused approaches of the UNFCCC and the Kyoto Protocol, also does not reference geoengineering. In the negotiation of the Paris Agreement, CDR was extensively discussed, and the Agreement has a number of provisions that would appear applicable to CDR.[55] In contrast, SRM is not even implicitly referred to in the Agreement, a result of concern that any discussion of SRM might derail the negotiations.[56]

Geoengineering has only made scant appearances elsewhere in international law. At the tenth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD), geoengineering was explicitly referred to in Decision X/33, adopted as part of that meeting. Paragraph (w) of Decision X/33 provides that:

> [I]n the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and

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53 UNFCCC, *supra* note 8, art. 3.3.

54 *See* Winter, *supra* note 14, at 998.

55 Joshua B. Horton, David W. Keith & Matthias Honegger, *Implications of the Paris Agreement for Carbon Dioxide Removal and Solar Geoengineering*, HARV. PROJECT ON CLIMATE AGREEMENTS: VIEWPOINTS, July 2016, at 1, 3. Article 4 of the Paris Agreement, for instance, refers explicitly to "removals by sinks of greenhouse gases" and provisions on market mechanisms could provide support for CDR technologies.

56 Kevin Keane, *Geo-Engineering the Climate: A Preliminary Examination of International Governance Challenges and Opportunities*, 23 TRINITY COLL. L. REV. 56, 73 (2020).

> biodiversity and associated social, economic and cultural impacts . . . .[57]

The Decision exempts small scale scientific research studies conducted in a controlled setting.[58] This cautious approach reflects the way the CBD has enshrined the precautionary principle.

The precautionary principle importantly does not apply to private individuals, and largely exists in the context of non-binding frameworks.[59] Furthermore, due to the uncertainty in how the principle has been interpreted across international law, in the context of geoengineering it can be viewed either justifying taking measures "to minimize the (unknown) risks to the environment and health," or alternatively to justify geoengineering as itself "a precautionary measure against the (known) risks of climate change."[60] The Organisation for Economic Co-operation and Development (OECD) has promulgated voluntary guidelines for multinational enterprises that recommend that enterprises account for the need to protect the environment and that they be governed by the precautionary principle and act proactively to minimize environmental damage resulting from their activities.[61] This focus on environmental damage could be applicable in the context of geoengineering, suggesting that multinational enterprises deploy geoengineering measures with caution.[62]

Other environmental law instruments that could be relevant to geoengineering include the Convention on Long-Range Transboundary Air Pollution, the Vienna Convention for the Protection of the Ozone Layer of 1985 and its Montreal Protocol of 1987, and the 1991 Convention on Environmental Impact

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57 United Nations Environment Programme, *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting, X/33, Biodiversity and Climate Change,* UNEP/CBP/COP/DEC/X/33, ¶ (w) (Oct. 29, 2010) [hereinafter *Decision X/33*].

58 *Id.*

59 Elizabeth Tedsen & Gesa Homann, *Implementing the Precautionary Principle for Climate Engineering*, 7 CCLR 90, 93-94 (2013).

60 *Id.* at 91.

61 OECD, *Chapter VI: Environment*, OECD GUIDELINES FOR MULTINATIONAL ENTERPRISES, 2011 EDITION 42, 45-46, ¶¶ 68-69. The *Guidelines* are "intended only to recommend how the precautionary approach should be implemented at the level of enterprises." *Id.* at 46, ¶ 70.

62 *See* Daniela Lai, *Deployment of Geoengineering by the Private and Public Sector: Can the Risks of Geoengineering Ever Be Effectively Regulated?*, 37 LOY. L.A. INT'L & COMPAR. L. REV. 341, 363-64 (2016).

Assessment in a Transboundary Context.[63] Discussion of these are outside the scope of this article. There are also a host of non-binding multilateral environmental agreements that offer guidance.

Key principles of international environmental law that underpin the legal regime include the polluter pays principle and the principle of transboundary harm. These principles, which found their first articulation in the *Trail Smelter* case, have been at the heart of international environmental law for decades.[64] Under polluter pays, the producer of the pollution has the responsibility of bearing the cost of managing the pollution to reduce harm to the environment and to people who are victims of the pollution.[65] The applicability of this principle to SRM mechanisms is clear: if a state or a private actor were to unleash an SRM mechanism that caused harm to private individuals within that state, there should be a liability mechanism to address compensation for those individuals. Similarly, Principle 13 of the Rio Declaration on Environment and Development notes that states should cooperate in further developing international law on liability and compensation. The importance of polluter pays lies in its applicability to private as well as state actors, unlike many other international law mechanisms and principles.

The principle of transboundary harm finds expression in the International Law Commission's Draft articles on Prevention of Transboundary Harm from Hazardous Activities.[66] Article 1 defines the scope of the articles as applying "to activities not

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63 *See* Gerrard, *supra* note 26, at 12-15.

64 *See* Trail Smelter Arbitration (U.S. v. Can.), 3 R.I.A.A Vol. III 1905, (Apr. 16, 1938 and Mar. 11, 1941) [hereinafter Trail Smelter Arbitration]; Rebecca M. Bratspies & Russell A. Miller, *Introduction, in* TRANSBOUNDARY HARM IN INTERNATIONAL LAW: LESSONS FROM THE TRAIL SMELTER ARBITRATION 1 (Rebecca M. Bratspies & Russell A. Miller eds., 2006).

65 The polluter pays principle is enshrined in Principle 13 of the Rio Declaration on Environment and Development (1992):

> States shall develop national law regarding liability and compensation for the victims of pollution and other environmental damage. States shall also cooperate in an expeditious and more determined manner to develop further international law regarding liability and compensation for adverse effects of environmental damage caused by activities within their jurisdiction or control to areas beyond their jurisdiction.

U.N. Conference on Environment and Development, *Rio Declaration on Environment and Development*, UN Doc. A/CONF.151/26 (Vol. I), annex 1 (Aug. 12, 1992).

66 Int'l Law Comm'n, Rep. on the Draft Articles on Prevention of Transboundary Harm from Hazardous Activities with Commentaries, U.N. Doc. A/56/10 (2001).

prohibited by international law and which involve a risk of causing significant transboundary harm through their physical consequences."[67] The "significant" standard originates in the ruling of the Tribunal in the *Trail Smelter* arbitration, which found that liability will ensue where "the case is of serious consequence and the injury is established by clear and convincing evidence."[68]

With geoengineering, since much of it is very difficult to test prior to deployment, there is a not insignificant risk of damage occurring because of the geoengineering itself. International environmental law offers a proactive ex ante avenue for mitigating those risks, through mandating the use of an environmental impact assessment (EIA) prior to the technology's deployment. In *Pulp Mills on the River Uruguay*, the International Court of Justice found that if there is a risk of the activity having a "significant adverse impact in a transboundary context," an EIA must be undertaken.[69] Where the potential danger is greater, the stringency of the EIA required should arguably increase proportionally.[70] It is clear, based on the risks of geoengineering, that many of the methods proposed, including stratospheric aerosol injections and space-based reflectors, would require EIAs because of their transboundary impacts.[71]

c. International Humanitarian Law

International law prohibits the use of force except in exceptional circumstances. Article 2(4) of the UN Charter prevents Members from "threat or use of force against the territorial integrity or

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[67] *Id.* ¶ 149.

[68] *Trail Smelter Arbitration*, *supra* note 65, at 1965.

[69] Pulp Mills on the River Uruguay (Arg. v. Uru.), Judgment, 2010 I.C.J. 14, ¶ 204 (Apr. 2010). From the judgment:

> In this sense, the obligation to protect and preserve, under Article 41 (a) of the Statute, has to be interpreted in accordance with a practice, which in recent years has gained so much acceptance among States that it may now be considered 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.

[70] Alexander Proelss, *Geoengineering and International Law*, 30 SEC. & PEACE 205, 206 (2012).

[71] Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 MICH. J. INT'L L. 309, 345 (2013).

political independence of any state."[72] While on its surface, it might seem a tenuous claim to link geoengineering with the threat or use of force, climate change may eventually result in a situation so grave that it causes a security crisis for a state, thus requiring that it act. In this area, the law of armed conflict provides some context, although a critical difference is that war "is waged with intent to harm"[73] and geoengineering lacks that intent. However, as Elizabeth Chalecki and Lisa Ferrari have argued, "when speaking of that scale of involuntary environmental change—that is a distinction without a difference."[74] Drawing on just war theory, they propose criteria for the deployment of geoengineering, including that the "estimated damage must meet some threshold in lives or dollars," the threat to security "must be publicly attributable to climate change" and the cost of climate change mitigation or adaptation must be too grew to afford to take too long to be effective."[75]

One instrument that has been mentioned in the context of geoengineering is the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD).[76] ENMOD requires that parties to the treaty "undertake[] not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party."[77] Article II defines "environmental modification techniques" as referring to "any technique for changing–through the deliberate manipulation of natural processes –the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space."[78]

With seventy-eight parties to the convention, including the United States and Russia, ENMOD might seem clearly applicable and of significant use with respect to geoengineering. However, since this pertains to "hostile use," this would seem to preclude its

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72 U.N. Charter art. 2, ¶ 4.

73 Elizabeth L. Chalecki & Lisa L. Ferrari, *A New Security Framework for Geoengineering*, 12 Strategic Stud. Q. 82, 87 (2018).

74 *Id.*

75 *Id.* at 95.

76 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, *opened for signature* May 18, 1977, 31 U.S.T. 333, 1108 U.N.T.S. 151 [hereinafter ENMOD].

77 *Id.* art. I.

78 *Id.* art. II.

applicability to geoengineering, which notwithstanding any potential harmful effect, is not something with a hostile intent. Article III of ENMOD explicitly states that "[t]he provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes and shall be without prejudice to the generally recognized principles and applicable rules of international law concerning such use."[79] Parties that might use geoengineering would be doing so to try to avert catastrophe relating to the effects of climate change, not to accelerate those effects. Even if geoengineering is used to address national security issues that "have become so severe that policy makers have begun to see geoengineering as a possible means of 'defense,'" this now gives rise to ethical questions relating to "whether or not such attempts could be both ethically acceptable and a net security gain."[80]

d. Space Law

Space-based reflectors implicate the outer space legal regime. Here, the connection between potential harm caused by state actors and liability ensuing from such actions becomes much clearer. The Outer Space Treaty is clear in establishing that the exploration and use of outer space "shall be carried out for the benefit and the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind."[81] From a geoengineering perspective, viewed in isolation, this suggests that states that deploy SRM mechanisms in outer space to reduce the effects of climate change across the planet would be permitted to do so. However, other provisions of the Outer Space Treaty make it clear that even well-intended actions in outer space that have negative consequences on Earth will carry with them responsibility and liability for the state deploying them.

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[79] *Id.* art. III; *see also* Karen N. Scott, *Engineering the 'Mis-Anthropocene': International Law, Ethics and Geoengineering*, 29 OCEAN Y.B. 61, 74 (2015) (describing ENMOD's "value as a broader framework for geongineering" as "limited" given Article III's protection of environmental modification for peaceful purposes).

[80] Chalecki & Ferrari, *supra* note 73, at 92.

[81] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies art. I, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

Article VI ascribes international responsibility for national activities in outer space to state parties.[82] Article IX states that all activities in outer space must be "guided by the principle of co-operation and mutual assistance" and must be conducted "with due regard to the corresponding interest of all other States Parties to the Treaty." Article IX further requires that activities be conducted in ways that avoid "adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter."[83] While SRM mechanisms as currently contemplated envisage the opposite –introducing Earth matter to outer space–states must be cautious in how they deploy SRM mechanisms, particularly if we reach the technological stage where assembly of SRM mechanisms in outer space using materials found in outer space becomes feasible. Most crucially, Article VII of the Outer Space Treaty sets out the basis for state liability, holding 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 by such object or its component parts on the Earth, in air or in outer space."[84]

From Article VII of the Outer Space Treaty comes the Liability Convention, which makes launching states "absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft flight."[85] The Liability Convention appears to focus on physical damage caused by space objects, and it is unclear if the Convention would apply to effects caused indirectly by space objects. Using the example of space reflectors, it would not be the space reflector itself that would cause damage to the Earth, but rather the effect of the space reflector in partially blocking the sun and resulting in whatever catastrophic environmental effects that might have.

Read together, the Outer Space Treaty and the Liability Convention suggest that any party that launches even a well-intentioned SRM mechanism in outer space that results in negative consequences to anyone on Earth, could be held liable for the damage. Even if a narrower reading of the Liability Convention is taken, the strict liability standard in that agreement indicates that

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[82] *Id.* art. VI.

[83] *Id.* art. IX.

[84] *Id.* art. VII.

[85] Convention on International Liability for Damage Caused by Space Objects art. II, Mar. 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187 [hereinafter Liability Convention].

concern regarding the possibility of space objects causing harm to humanity is very real. The drafters could not have contemplated the possibility of geoengineering at the time the Convention was agreed, and it is possible that their intention would have extended to include indirect damage where the "but for" cause was the deployment of the space object in question, despite the space object not being the primary physical actor in causing the damage.

The liability regime found in the Liability Convention is unique in international law as the only example based entirely on state liability.[86] While the Liability Convention itself may have limited applicability to geoengineering, since space-based reflectors remain a cost-prohibitive and largely speculative mechanism, it can serve as a model for an international liability regime that would be applicable to geoengineering more broadly.[87] Unlike state responsibility, which only applies where states violate their international obligations, state liability means that a state may be found liable for damages even where it has exercised due diligence and where the actions it has taken are lawful.[88]

e. Public International Law

All the previously discussed legal areas form *lex specialis*, and as such have significant overlap with core principles of customary international law. Article III of the Outer Space Treaty, for instance, expressly refers to carrying on activities in the exploration and use of outer space "in accordance with international law."[89] Some of these international principles are at odds with each other, however, including the state's right to exploit sovereign natural resources and the obligation on states to avoid transboundary harm.[90]

The principle of necessity may also offer states an avenue to conduct geoengineering activities. Necessity is defined in Article 25 of the Articles on Responsibility of States for Internationally

[86] Joshua B. Horton, Andrew Parker & David Keith, *Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities*, 22 N.Y.U. ENV'T. L.J. 225, 233-34 (2015).

[87] Tracy Hester, *Liability and Compensation*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 224, 249 (Michael B. Gerrard & Tracy Hester eds., 2018).

[88] Horton, Parker & Keith, *supra* note 86, at 233-34.

[89] Outer Space Treaty, *supra* note 81, art. III.

[90] Gerrard, *supra* note 26, at 16.

Wrongful Acts.[91] States cannot invoke necessity as a justification for taking an internationally wrongful act unless the act is the only way for the State to safeguard an essential interest against a grave and imminent peril; and does not seriously impair an essential interest of the State or States towards which the obligation exists, or of the international community as a whole.[92] States are further limited insofar as they cannot invoke necessity if the state contributed to the situation of necessity.[93]

In the context of climate change, if a state were to unilaterally engage in geoengineering in a way that constituted an internationally wrongful act, it could argue that the act was necessary to safeguard its survival in light of the peril of climate change. Depending on the effects of the geoengineering, however, the act could seriously impair an essential interest of the other state. Furthermore, envisioning a situation where the unilateral actor is a state that is a major GHG emitter, that state would arguably be precluded from invoking necessity since it contributed to the situation of necessity through its emissions. The likelihood that a unilateral geoengineering actor would also be a major GHG emitter is high.

Running as a current through all of these different areas of law is the question of liability. From the polluter pays principle and the idea of transboundary environmental harm to the Liability Convention in the space law regime, a liability regime provides the most immediate form of legal resolution, by offering a compensatory means to rectify the damage caused. What standard applies, however, varies across legal agreements. Liability will be further discussed below.

IV. ISSUES WITH SRM

SRM remains problematic from both a legal and a moral perspective. As a starting point, in relation to many of the SRM

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91 Int'l Law Comm'n, Rep. on the Draft Articles on the Responsibility of States for Internationally Wrongful Acts with Commentaries, 56 U.N. GAOR Supp. No. 10, art. 24, U.N. Doc. A/56/10 (2001) [hereinafter Articles on Responsibility of States for Internationally Wrongful Acts].

92 *Id.* art. 25(1).

93 *Id.* art. 25(2).

mechanisms proposed, research itself is dangerous. As Gerd Winter has argued:

> It is not just the large-scale deployment of climate engineering technologies that bears risks. Research into climate engineering methods also poses a threat. It is predicted that *in situ* experiments themselves could constitute a major intervention of significant duration, because a large-scale field trial would be necessary to determine whether the experiment has produced intended cooling separate from the usual temperature fluctuations.[94]

At the same time, not conducting research gives rise to the potential for deployment of largely untested SRM mechanisms should the climate crisis worsen to such a point that no alternative appears possible.

As mentioned at the outset of the article, there are four primary categories of risk: the risk of geoengineering, the risk of unilateral state action, the risk of unilateral private action, and the risk of doing nothing. Through the brief examination and evaluation of each of these risks that follows, this section lays the groundwork for the broader reflections on potential solutions and limitations that a legal regulatory regime might have.

a. Risk of Geoengineering

Perhaps the most frequently cited risk of geoengineering is the moral hazard risk. The concern that geoengineering research and deployment might undermine climate mitigation efforts, including the imperative requirement to reduce GHG emissions, permeates much of the academic and policy literature.[95] The moral hazard problem is real, with studies showing that individuals and societies engage in more risky behavior when there is a transfer of risk.[96] The

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[94] Winter, *supra* note 14, at 983.

[95] *See, e.g.*, Gerrard, *supra* note 26, at 11; CARROLL MUFFETT & STEVEN FEIT, CTR. FOR INT'L ENV'T L., FUEL TO THE FIRE: HOW GEOENGINEERING THREATENS TO ENTRENCH FOSSIL FUELS AND ACCELERATE THE CLIMATE CRISIS 46 (2019) ("Most proponents of geoengineering research acknowledge the political and moral hazard risks of geoengineering and even acknowledge how these ideas can be used by those opposed to emissions reduction."); Lin, *supra* note 28, at 2544.

[96] Albert C. Lin, *Does Geoengineering Present a Moral Hazard?*, 40 ECOLOGY L.Q. 673, 688 (2013).

moral hazard with geoengineering is that it "[m]ight be perceived as an insurance policy against climate change, undermining support for existing climate policies."[97] The challenge with geoengineering is, therefore, the inverse of that of climate mitigation. Mitigation requires all actors to do more, while geoengineering will require limiting those with the capability to act "from doing too much, too soon."[98]

On a more implementation-focused level, geoengineering, as discussed above, could result in a termination problem whereby if CO_2 emissions are not decreased while the SRM mechanism is in place, once it ends, there will be a rapid increase in temperature, particularly if the SRM has been in place for a long time. The effects of such rapid termination could arguably be more severe than those of gradual climate change, with reduced adaptation opportunities, including less of a chance for population migration.[99] It is therefore not enough for a legal regime to address issues pertaining to geoengineering research and initial deployment—the legal regime must also be able to address how to terminate the SRM.

The "lock-in" effect poses another risk, with the potential for certain technologies to become locked in and thus dominate the area of SRMs, even where newer, more efficient technologies are being developed. Lock-in has occurred with fossil fuels, whose dominance has locked-in the technologies dependent on fossil fuels, through extensive and long-lived infrastructure and the interrelated components.[100] It has also occurred with first generation climate change-related technologies, including corn ethanol as a biofuel.[101] Lock-in may result from early advantages or from chance circumstances, including economic factors such as economies of scale, and political and social factors such as support and investment in perpetuating certain technology from politicians, corporations, or other entities.[102]

Legally, the risks of geoengineering and particularly SRM mean that the existing legal infrastructure (or lack thereof) is inadequate. While an EIA would provide some assessment of risk and could

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97 Adam Corner & Nick Pidgeon, *Geoengineering, Climate Change Scepticism and the 'Moral Hazard' Argument: An Experimental Study of UK Public Perceptions*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A., Dec. 28, 2014, at 1, 2.

98 Reynolds, *supra* note 31, at 7.

99 Williams et al., *supra* note 23.

100 Lin *supra* note 29, at 2542.

101 Lin *supra* note 17, at 145.

102 Lin, *supra* note 29, at 2541.

help determine whether or not a particular geoengineering project should move forward, the impossibility of conducting large-scale testing means that there will always be potential unanticipated adverse consequences.[103] While it may seem reassuring that solar reflectors in outer space are governed by the Liability Convention, where such mechanisms cause irreversible changes to the Earth's environment, no amount of ex post damages can compensate for the ensuing harm caused, and there is no comprehensive liability regime that would apply to non-space-based geoengineering efforts.

By framing geoengineering in the context of intergenerational equity, the temporal risk of SRM becomes clear. Intergenerational equity centers around "fairness in the utilization of resources between human generations past, present and future."[104] Certain SRM mechanisms may require legal governance that spans centuries,[105] not the decades that our legal regimes are typically constructed around. Even in the shorter term, SRM may impact weather patterns, reducing precipitation and depleting the ozone layer.[106] The impact of SRM may limit climate change policy options for future generations, as well as potentially creating negative climatic impacts.[107] In addition to these challenges, long-term governance requires anticipating what the priority of states may be in the future, and what the face of international relations may look like.[108] There is not much in the way of precedent for this level of intensive, long-term governance.

b. Risk of Unilateral State Action

In light of the many risks relating to geoengineering, efforts to research and deploy SRM require multilateral coordination, involving states as well as individuals. Right to information, right to participation, and access to remedies are critical human rights that

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103 Lai, *supra* note 62, at 354.

104 G.F. Maggio, *Inter/Intra-generational Equity: Current Applications Under International Law for Promoting the Sustainable Development of Natural Resources*, 4 BUFF. ENV'T. L.J. 161, 163 (1997).

105 MacMartin, Ricke & Keith, *supra* note 21, at 13.

106 Burger & Gundlach, *supra* note 18; Reynolds, *supra* note 31.

107 Burns, *supra* note 43, at 41.

108 Reynolds, *supra* note 43, at 6-7.

are necessary for meaningful, inclusive environmental protection.[109] Unlike emissions reductions which require coordinated action from all global constituents, from states through corporations through individuals, geoengineering can easily be deployed unilaterally, while having global impact.[110] Crucially, international law is defined by states and it is within state sovereignty to decide how to act, since states ultimately retain the ability to enforce international law and to select which rules, outside of the limited principles of customary international law and *jus cogens* norms, they choose to be bound by. This limits the ability for international law to bind states through future multilateral agreements designed to constrain the ability of states to deploy SRM mechanisms.[111]

With respect to the risk of unilateral state action, unilateral deployment of geoengineering may give rise to significant security hazards, notably "the risk of breakdown of interstate cooperation—including, ultimately, war."[112] In relation to stratospheric aerosol injections, the security risks posed are novel and have the potential to be as disruptive in the 21st century "as nuclear weapons were for the 20th."[113] Failure of SRM mechanisms could drastically alter weather patterns, for instance creating conflicting interests between China and India over monsoon rains.[114] To take one example, if solar reflectors are deployed at a LaGrange point, the sun will be blocked in ways that affects the entire planet. Any discussion of such methods should take place on a multilateral basis since everyone will be affected.

The reality of SRM is that some of the mechanisms, particularly stratospheric aerosol injections, are relatively low-cost, which makes these mechanisms accessible to a wide variety of actors, including smaller states.[115] Much of the discussion on the risks of geoengineering has centered on the technological and financial disparity between Global North and Global South countries and the possibility that Global North states, the primary drivers of climate

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109 Railla Veronica D. Puno, *A Rights-Based Approach to Governance of Climate Geoengineering*, 50 ENV'T L. REP. 10744, 10748 (2020).

110 Scott, *supra* note 71, at 354.

111 Reynolds, *supra* note 43, at 6-7.

112 Olaf Corry, *The International Politics of Geoengineering: The Feasibility of Plan B for Tackling Climate Change*, 48 Sec. Dialogue 297, 301 (2017).

113 *Id.* at 302 (citing DAVID KEITH, A CASE FOR CLIMATE ENGINEERING x-xi (2013)).

114 *Id.*

115 Lockley, Guterman & Coffman, *supra* note 16.

change, would unilaterally deploy geoengineering without consulting with Global South countries, which are particularly vulnerable to the effects of climate change. Another framing envisions a small island state facing inundation and deciding to unilaterally deploy geoengineering as a last resort.[116] Both framings are important to bear in mind, as both scenarios involve a risk of unilateral state action.

As previously discussed, one of the great concerns involving SRM is the moral hazard issue, "that the belief it could work could induce some people to be less diligent in pursuing the far superior (but more expensive) pathway of mitigation."[117] Here, the risk of unilateral private action operates in tandem with the risk of unilateral state action. Recent news reports indicate that climate change skeptics are turning towards geoengineering as the realities of climate change become overwhelming.[118] Much of this research is by private companies. At the international level, states are refusing to disclose geoengineering research and have rebuffed proposals that would require greater transparency and cooperation.[119]

c. Risk of Unilateral Private Action

Whereas there are international legal rules that apply to states and that may give them pause in deciding whether or not to pursue unilateral state action with respect to geoengineering, such rules do not apply to private individuals. Elizabeth Tedsen and Gesa Homann have described the fear of a "Greenfinger"—what they describe as a "single actor with the power to shape the global environment."[120] They give the example of a July 2012 private ocean fertilization experiment carried out by an American businessman, Russ George, which resulted in a lot of media attention but no legal

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[116] Lockley, Guterman & Coffman, *supra* note 17.

[117] Gerrard, *supra* note 26, at 11.

[118] Katherine Ellison, *Why Climate Change Skeptics Are Backing Geoengineering*, WIRED (Mar. 28, 2019, 08:00 AM), https://www.wired.com/story/why-climate-change-skeptics-are-backing-geoengineering/ [https://perma.cc/CC8X-V23D].

[119] Jean Chemnick, *U.S. Blocks U.N. Resolution on Geoengineering*, SCI. AM. (Mar. 15, 2019), https://www.scientificamerican.com/article/u-s-blocks-u-n-resolution-on-geoengineering/ [https://perma.cc/B6FE-U23S].

[120] Tedsen & Homann, *supra* note 59, at 94.

action, since he was not in breach of international law.[121] In this experiment, the Haida tribe were given misleading information by George regarding the intent of the project, and were not informed of the risks or the international legal status of ocean fertilization.[122] The danger of misinformation exists no matter the actor (whether state or private), but is heightened with private actors who, unlike states, have no obligations to constituents other than perhaps to their shareholders.

Much like with unilateral state action, the low-cost aspect of certain SRM mechanisms makes the possibility of unilateral private action more likely.[123] Whether motivated by profit or philanthropy, there is little standing in the way of private actors acting unilaterally. International law does not address private actors, and there is no binding multinational corporate governance in any area of the law, only a patchwork of domestic regulations (which in many areas, such as geoengineering, is limited if not nonexistent) and voluntary corporate guidelines such as the OECD ones discussed above. Customary international law imposes obligations on states to conducts EIAs, for instance, but this obligation does not apply to private entities and individuals.[124] The best example of an effort to enact binding international regulation of corporations in the area of environmental law is the Convention on the Protection of the Environment through Criminal Law, which requires state parties to establish as criminal offences certain environmental offenses, primarily relating to pollution.[125] While this criminal liability regime might sound promising, the treaty, concluded by the Council of Europe and opened for signature in 1998, only has thirteen signatories and one ratifying party (Estonia).[126] Without widespread approval, such initiatives are dead in the water.

In the United States, the Weather Modification Reporting Act of 1972 applies to both public and private activities, whether federal or non-federal, but such instruments are insufficient to stop unilateral

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[121] Tedsen & Homann, *supra* note 59, at 94.

[122] Lai, *supra* note 62, at 362-63.

[123] Scott, *supra* note 79, at 81.

[124] Lai, *supra* note 62, at 361.

[125] Convention on the Protection of the Environment through Criminal Law art. 2-3, April 11, 1998, E.T.S 172.

[126] *Chart of signatures and ratifications of Treaty 172, Status as of 07/03/2021*, COUNCIL OF EUROPE, https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/172/signatures?p_auth=HTvQSiUD [https://perma.cc/Q68R-S9BN].

private actors, particularly where all they impose is a duty to report.[127] Private actors should not be more than ancillary participants in decision-making relating to geoengineering, since the potential impacts are global and commercial interests should not prevail.[128] States are, of course, also flawed actors in the context of geoengineering, being driven by self-interest and self-preservation, but as they owe an obligation to their citizens and remain the key players in international law, they are better suited to developing a global governance regime.

One argument against the likelihood of unilateral private action in the realm of geoengineering is the lack of profitability in the deployment of such technology.[129] For the wealthiest individuals on the planet, the possibility of being heralded as a planetary savior might be enough to motivate unilateral action—viewed as philanthropy or altruism while actually reflecting a level of narcissistic paternalism towards the world's population. The estimated cost of stratospheric aerosol injections[130] is already well within the reach of the world's wealthiest individuals, who individually have a greater net worth than many countries' annual GDPs.[131] A bigger deterrent may be the international backlash against unilateral private action, particularly where certain SRM mechanisms, like stratospheric aerosol injections, require concerted, repeated actions, such as thousands of flights in a single year.[132] It would certainly be feasible for the international community to stop such unilateral action by grounding the necessary flights.

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[127] Albert C. Lin, *US Law*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL 154, 160 (Michael B. Gerrard & Tracy Hester eds., 2018); *see also* NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 136-37 (defining terms and explaining the purpose and statutory framework of the Weather Modification Reporting Act of 1972).

[128] *See* Horton, Parker & Keith, *supra* note 86, at 245-46.

[129] *See* Reynolds, *supra* note 43, at 18.

[130] *See, e.g.*, Smith & Wagner, *supra* note 50, at 1-2 (estimating an annual cost of $2.25 billion/year over the first 15 years of deployment).

[131] *See* Robert Frank, *Elon Musk is now the richest person in the world, passing Jeff Bezos*, CNBC (Jan. 7, 2021, 10:17 AM), https://www.cnbc.com/2021/01/07/elon-musk-is-now-the-richest-person-in-the-world-passing-jeff-bezos-.html [https://perma.cc/2PWZ-592Y] (noting that as of January 7, 2021, Elon Musk was worth $185 billion and Jeff Bezos was worth $184 billion).

[132] *See* Smith & Wagner, *supra* note 50, at 9.

d. Risk of Doing Nothing

Skepticism of geoengineering and all its associate risks is warranted, especially if it becomes a substitute for necessary emissions abatement, without which there can be no real mitigation of climate change. The risks of geoengineering have been amply discussed above. There is another risk, however, which is the risk of foreclosing the possibility of using geoengineering to address climate change, i.e., the risk of doing nothing.

In Kim Stanley Robinson's 2020 climate fiction novel, *The Ministry of the Future*, a prolonged heat wave in India with wet-bulb temperatures of over 35°C results in the death of twenty million people. In the wake of the tragedy, the government of India decides to move ahead unilaterally with the deployment of stratospheric aerosols to create a Mount Pinatubo effect, lowering temperatures in the short-term. While Robinson's novel is, of course, fiction, the reality of climate change means that we are seeing more instances of extreme heat and humidity posing danger for human survival.[133] A wet-bulb temperature of 35°C marks the combination of heat and humidity past which human survival becomes impossible with prolonged exposure, and has already been observed multiple times for short durations.[134] If emissions continue at the rate they are going (the "business-as-usual" emissions scenario), modeling studies suggest that by the third quarter of the 21st century, wet-bulb temperatures over 35°C could be regularly seen in parts of South Asia and the Middle East.[135]

In light of the devastation that extreme temperatures and other climate change-related weather events could cause, geoengineering may become a necessary arrow in the quiver of climate adaptation and mitigation techniques, each of which contributes individually to keeping the planet inhabitable. Before geoengineering mechanisms can be deployed, however, there must be robust, monitored

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133 Colin Raymond, Tom Matthews & Radley M. Horton, *The Emergence of Heat and Humidity Too Severe for Human Tolerance*, 6 SCI. ADVANCES, May 8, 2020, at 1.

134 *Id.* at 1.

135 *Id.*:

> A normal internal human body temperature of 36.8° ± 0.5°C requires skin temperatures of around 35°C to maintain a gradient directing heat outward from the core (10, 13). Once the air (dry-bulb) temperature (T) rises above this threshold, metabolic heat can only be shed via sweat-based latent cooling, and at TW exceeding about 35°C, this cooling mechanism loses its effectiveness altogether.

research. A moratorium on geoengineering research would potentially have long-term consequences, leading to states making uninformed and desperate decisions to deploy untested SRM or other geoengineering mechanisms.[136] Research carries its own risks, but those risks are accompanied by increases in knowledge regarding the viability of various technologies.[137]

A common critique of geoengineering is that is driven by, and for the benefit of, the Global North. As will be discussed below, there are many aspects of the proposed research and governance regimes that are troubling from a development perspective. Climate change is largely caused by the Global North, while the Global South bears the brunt of its effects.[138] With climate risks greater in the Global South, geoengineering may offer an opportunity to save lives and avert the kind of disaster described by Kim Stanley Robinson.

SRM is particularly suited to contributing to a reduction in global temperatures, which is the focus of the international climate change regime. The Paris Agreement set a temperature warming limit of 2°C above pre-industrial levels, with an optimistic goal of limiting the increase to 1.5°C.[139] The 1.5°C temperature limit is already out of reach, with increases in temperature of up to 2.7°C by the end of the century now the most optimistic forecast in the wake of the COP26 climate summit.[140] If emissions reduction goals are not met, SRM may become necessary to avert catastrophic warming.[141] In this light, SRM may even be viewed as being in accordance with principles of intergenerational equity, by protecting future generations from the harmful effects of unmitigated climate change.[142] It is important to remember, however, that geoengineering is "a bandage to cover the wound that failing to act would inflict on our successors on this planet."[143]

Adaptation is more uncertain than mitigation and cannot substitute for mitigation. The risks of geoengineering, and

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136 *See* Reynolds, *supra* note 43, at 15.

137 *See* Lin, *supra* note 17, at 146.

138 *See* Horton, Parker & Keith, *supra* note 86, at 243-44.

139 Paris Agreement, *supra* note 10, art. 2.

140 *See* Leslie Hook, *Global warming of up to 2.7C by century's end forecast as COP26 pledges fall short*, FIN. TIMES (Nov. 9, 2021), https://www.ft.com/content/b9a55763-f28a-46ad-b265-79db73efa658 [https://perma.cc/W57T-NF9E].

141 *See* Reynolds, *supra* note 43, at 2.

142 Burns, *supra* note 43, at 53.

143 Burns, *supra* note 43, at 53.

particularly the moral hazard that it entails, mean that all geoengineering research must be conducted cautiously and that any deployment efforts be matched with accompanying mitigation efforts. As will be discussed below, one solution may be to couple technologies—to require emissions reductions to accompany stratospheric aerosol injections of sulfates, for instance. But it is too late to pretend that our planet will have a future without every possible arrow in the quiver to combat climate change, and for that reason, the risk of doing nothing and pretending that geoengineering does not exist and will not be used is arguably too great of a risk.

V. PROPOSED SOLUTIONS AND LIMITATIONS

Geoengineering requires participatory governance. To the extent that we are considering such actions, multilevel negotiations must take place. This would require the involvement of NGOs, citizen groups, and other voices that usually do not have a seat at the international law negotiating table. As the Royal Society noted in a report on geoengineering from 2009, "[t]he central problem for the governance of geoengineering is that while potential problems can be identified with all geoengineering technologies, these can only be resolved through research, development and demonstration."[144] As much as we might like to prohibit geoengineering research due to the very real risks of catastrophic planetary destruction that geoengineering might cause, the possibility that we will face climate catastrophe requiring the deployment of geoengineering methods to save us from extinction is also a real possibility.

Analogues to the challenges facing geoengineering governance may be found in two different contexts: the planetary defense context and the nuclear non-proliferation context. The former reflects the struggles of achieving multilateral action and the relative successes of a piecemeal approach; the latter, while state-centered, also carries with it the possibility of rogue private actors.

While efforts to reach a multilateral agreement on how to deal with planetary defense against near-Earth objects have thus far fallen short, global recognition of the risks posed by near-Earth objects has resulted in a number of initiatives by unilateral state

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[144] The Royal Society, *supra* note 12, at 37.

actors with multilateral support.[145] This model offers a cooperative alternative for multilateral agreements that could be applicable in the SRM context. At the same time, in discussions of planetary defense and near-Earth objects, we are looking at scenarios that require cooperative action and where inaction would clearly cause significant harm to the planet.[146] Action by a state to divert a near-Earth object that resulted in it causing damage to property or human life in another state would clearly give rise to liability under the Liability Convention's strict liability standard. With geoengineering, the path of inaction does not carry any immediate risk—the latent risk there is that once climate change has progressed too far, we will lack the technology to deploy last-ditch geoengineering mechanisms. However, the incentive to conduct research on a unilateral basis and even to deploy it on a unilateral basis is much greater, since the applicability of the Liability Convention and other aspects of international law, as we have seen, is less clear-cut than in the context of planetary defense.

In relation to nuclear non-proliferation, the Treaty on the Non-Proliferation of Nuclear Weapons has 191 state parties, including all five countries that officially have nuclear weapons.[147] Concluded in 1968, the goal of the treaty was to prevent states from gaining nuclear weapons and to encourage states with nuclear weapons to disarm.[148] The preamble of the treaty recognizes the "devastation that would be visited upon all mankind by a nuclear war and the consequent need to make every effort to avert the danger of such a war and to take measures to safeguard the security of peoples."[149] The safeguards regime established by the treaty requires inspections by the International Atomic Energy Agency to verify compliance with the treaty.[150]

This model provides a good example of the kind of oversight that would be required to ensure that any geoengineering research was conducted in responsible and supervised manner. The drawback, of course, is the lack of political capital to conclude such a multilateral treaty with such universal buy-in with respect to

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[145] *See* SECURE WORLD FOUND., NEAR EARTH OBJECTS: RESPONDING TO THE INTERNATIONAL CHALLENGE 8-9.

[146] *See id.* at 7.

[147] *See* Treaty on the Non-Proliferation of Nuclear Weapons, 22 Apr. 1970, 21 U.S.T. 483 (NPT), 729 U.N.T.S. 161; 7 ILM 8809.

[148] *See id.* arts. III, VI.

[149] *Id*. Preamble.

[150] *Id*. art. III.

geoengineering as compared to nuclear weapons. It almost seems as if the only way to reach multilateral cooperation on geoengineering would be to have a failed geoengineering experiment with devastating consequences for a small portion of the world, in much the same way that the United States' use of nuclear weapons against Japan and the subsequent arms race with Russia frightened all countries, including the superpowers, into agreeing to an effective détente.

The dangers of unfettered deployment of SRM mechanisms give rise to a pressing need for solutions that would alleviate the gaps in the existing legal regime. A multilateral treaty with enforcement capabilities does not seem a likely possibility at the moment, nor would it address the dangers of private entities deploying SRM mechanisms. While the UNFCCC and Paris Agreement framework offer an avenue for opening discussions on SRMs, an alternative approach would see "a narrower group of states with interests in conducting SRM research" leading the research, eventually leading to "a fully inclusive governance approach," which is necessary "given the global implications of SRM."[151] Proposals that would leave certain states at the fringes of geoengineering governance, however, give rise to significant problems.[152] While some states may struggle to fully participate in a geoengineering governance regime, the possibility that Global South countries will find themselves marginalized and omitted from discussions is troubling. One needs only look at the Antarctic Treaty regime and concerns over the lack of decision-making power given to state parties that have not been "conducting substantial scientific research activity" to see the disparate and unequal effects that such a tiered treaty system gives rise to.[153]

One of the simplest SRM mechanisms to monitor is large-scale albedo changes. Satellites can be used to detect the "unilateral and uncoordinated deployment of albedo modification activities . . . ."[154] However, the capacity to launch satellites is limited to a small

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151 A. NEIL CRAIK & WILLIAM C.G. BURNS, CTR. FOR INT'L GOVERNANCE INNOVATION, CLIMATE ENGINEERING UNDER THE PARIS AGREEMENT: A LEGAL AND POLICY PRIMER 11 (2016).

152 *See e.g.,* Adam D.K. Abelkop & Jonathan C. Carlson, *Reining in Phaëthon's Chariot: Principles for the Governance of Geoengineering*, 21 TRANSNAT'L L. & CONTEMP. PROBS. 763, 798 (2013) (noting that "[f]ailure to participate in the treaty structure should not, however, mean that states completely forfeit their sovereign right to be notified and consulted with respect to activities that might affect them").

153 Antarctic Treaty, art. IX(2), Feb. 15, 1960, 12 U.S.T., 402 U.N.T.S. 71.

154 NAT'L RSCH. COUNCIL OF THE NAT'L ACADS., *supra* note 18, at 137.

number of countries. Transparency and information sharing is imperative to prevent those economically developed, mostly Global North countries from dominating the geoengineering governance landscape. Access to satellite technology and global information systems is necessary to establish breach of the duty to respect the environment, which requires showing that the geoengineering is attributable to the state in question and that it is the geoengineering activity that has caused the harm.[155]

Global governance notions that would prioritize the involvement of countries that have the capacity to develop and deploy SRM mechanisms entrench the existing problems with an international legal system that privileges Global North countries over Global South countries. This neo-colonial mentality is unacceptable in the context of global geoengineering. Without involving stakeholders that go beyond the large economies, there should be no discussion of deploying SRM mechanisms.

SRM is novel and untested and in many ways unique, which makes coming up with regulatory solutions particularly difficult. An analogy can be drawn with geoengineering proposals relating to ocean fertilization, which would seed the ocean with iron particles to increase plankton blooms, and thus capture more carbon dioxide from the atmosphere.[156] Here, this gives rise to the problem of "permissible pollution" by which certain types of pollution may be viewed as an acceptable means of addressing climate change.[157] Benjamin Hale and Lisa Dilling have argued that:

> [O]cean fertilization is impermissible by virtue of its scope and scale, because of the extent to which it is (1) caught up in the antecedent and continuing actions of distributed actors and (2) virtually impossible to arrive at a mutually respectful outcome. In addition, we observe that (3) conducting ocean fertilization moves the world to an unknown "third state[.]"[158]

This unknown "third state" represents such a fundamental shift in our understanding of how our planet functions that unilateral action cannot be permitted. Further, even cooperative action

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155 Bodle, *supra* note 43, at 306.

156 *See* Benjamin Hale & Lisa Dilling, *Geoengineering, Ocean Fertilization, and the Problem of Permissible Pollution*, 36 SCI. TECH. & HUM. VALUES 190, 192 (2011).

157 *See id.* at 197.

158 *Id.* at 196.

involving decisions by state actors would disenfranchise those who might be most severely affected: indigenous people, poor people, and others without the means to relocate should something go awry.

SRM should be viewed as a public activity, and in this context, a state liability regime might provide an avenue for regulation.[159] Horton et al. have drawn an analogy between the oil spill liability regime and SRM liability, suggesting that since compensation levels have been adequate to satisfy damage claims resulting from oil spills, this might be an appropriate model for SRM to follow.[160] The oil spill regime imposes liability onto private as well as public parties, and it is suggested that payments under the liability regime have had a deterrent effect, encouraging the oil industry to take preventative safety measures.[161] Both of these claims raise some questions. First, adequate compensation is taken to mean that there has nearly always been compensation available to pay claims resulting from oil spills,[162] which is normatively quite different from the claim that the compensation is adequate to compensate for losses incurred as a result of oil spills. Second, the analogy between SRM and the oil industry quickly breaks down upon closer inspection: the oil industry is for profit, while SRM is not; while oil spills can be environmentally devastating, they are generally more limited in scope, both temporally and geographically, than SRM is likely to be.

Liability regimes are perhaps the most popular, straightforward, and satisfying solution to the SRM governance gap. Yet in many ways, a liability regime for geoengineering would be a governance Band-Aid in much the same way that geoengineering is itself a Band-Aid for climate change. The moral hazard risk of geoengineering—that states will reduce efforts to mitigate climate change in reliance on the quick fix of geoengineering—applies to liability regimes as well. A liability regime for SRM may result in states and the international community reducing their efforts to develop more robust governance strategies. Law tends to like *ex post* solutions like liability regimes. We most often punish behavior that has already happened, rather than preventing it from occurring. With geoengineering, *ex post* solutions are clearly inadequate to prevent the risk of unilateral action from states or private individuals. This is not to say that liability regimes are a bad idea—

159 *See* Horton, Parker & Keith, *supra* note 86, at 245-46.
160 *See* Horton, Parker & Keith, *supra* note 86, at 257.
161 *See* Horton, Parker & Keith, *supra* note 86, at 256.
162 *See* Horton, Parker & Keith, *supra* note 86, at 257.

they are absolutely necessary to provide those affected with a means of compensation should geoengineering, whether sanctioned or not, result in harmful effects. After all, unlike state responsibility, state liability applies even where the conduct is not illegal and with the uncertainty of the effects of geoengineering, such a regime is needed. A state liability regime for SRM would also require holding states responsible for unilateral private action that is deployed from the territory of that state.

Ultimately, *ex ante* regulatory solutions like the nuclear non-proliferation regime need to be implemented in tandem with *ex post* liability schemes for there to be effective governance of SRM. Whether this is possible depends in part on whether states can come to an agreement regarding the acceptability of geoengineering, which in turn depends on whether fundamental differences between Global North and Global South approaches to addressing climate change can be resolved. This requires multistakeholder governance, whereby voices from indigenous and local communities are included in the discussions, echoing the call made in CBD Decision X/33.

VI. CONCLUSION

Geoengineering seems increasingly inevitable. Despite significant academic and policy work attempting to address the legal and governance regime surrounding it, the problem of rogue actors has been largely overlooked. Our liability regimes, whether based on transboundary harm, polluter pays principles, or on the Liability Convention in outer space, always view redressing harms in an *ex post* fashion. Where the risks are such that deployment of geoengineering mechanisms could result in irreversible harm to the planet, this system is inadequate. Further, as wealth becomes concentrated in the hands of a small number of multi-billionaires, the argument that logistically, geoengineering is outside the scope of an individual's action becomes weaker. It is not unreasonable to imagine a situation in which an individual would decide to act benevolently to save the planet, and unwittingly doom it. International law remains state-based, and there is no international mechanism whereby private actors could be prevented from acting.

While banning all research on geoengineering might seem like a safe solution, there is no guarantee that states and individuals would adhere to such a ban. Furthermore, using geoengineering that has not been adequately tested and researched in a future crisis situation where climate change has become so disastrous that the balancing of the precautionary approach has shifted to a state where the risks of doing nothing outweigh the risks of geoengineering would itself have potentially catastrophic consequences.

Implementing something akin to a nuclear non-proliferation regime with multilateral inputs from state as well as non-state parties would be an important step to formalizing a legal geoengineering governance regime. Unfortunately, as we see increasing international fragmentation and disagreement over geoengineering, the divide between Global South and Global North countries comes to the forefront. The legacy of colonialism can yet again be seen in the disagreement over how to approach geoengineering. Where a small number of states and private actors have the resources to unilaterally deploy geoengineering mechanisms, it is unlikely that they will listen to the concern of those states that are the most economically and environmentally vulnerable as a result of the historical actions of those economically dominant, primarily Global North states.

As a planet, we need to come together to reduce our consumption of resources and pivot away from our extractive practices, rather than rely on technological quick-fixes like geoengineering. Unfortunately, if there is a lesson to be learned from the responses of countries and people to the COVID-19 pandemic, it is that many of our societies, particularly in the Global North, are too individualistic and selfish to make necessary lifestyle changes to avert catastrophe. The prognosis for climate change mitigation and GHG emission reduction in the short-term is grim. In the long-term, it will be too late to rely on mitigation efforts alone. It already may be too late.