Modifying the Weather: A Proposed Regulatory Framework Governing Stratospheric Aerosol Injection Climate Interventions

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As the climate crisis worsens, climate engineering—a previously disfavored tool—appears more attractive. Stratospheric aerosol injection ("SAI"), the most promising climate engineering technique, mimics the cooling effect of volcanic eruptions by dispersing aerosols at high altitudes to deflect solar radiation. Private actors have already begun deploying SAI with minimal oversight and interest in large-scale deployment of SAI continues to grow. As other commentators describe, SAI is harsh medicine; it carries serious risks, but many experts think it is necessary to avoid the worst consequences of climate change. While critics call for an all-out ban, operators are free to experiment or implement so long as they merely report their activities to the National Oceanic and Atmospheric Administration ("NOAA") under the Weather Modification Reporting Act of 1972 ("WMRA") unless their actions fortuitously trigger other federal or state environmental statutes. This Note rejects both a categorical prohibition on SAI and the existing reporting regime and argues that NOAA possesses statutory authorization under the WMRA to meaningfully regulate SAI. Part I surveys the history and modern implementations of SAI. Part II contemplates the most likely private-sector SAI project to develop. Part III proposes a tiered regulatory framework that categorizes activities as either high-impact or lower-impact and requires public notification for high-impact activities. This proposed framework would fill existing gaps in the regulation of SAI by creating transparency and leveraging the deterrent effect that flows from public notification.

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INTRODUCTION

In 2024, global temperature reached a record high, averaging 1.5°C above the pre-industrial average.[1] For many years, scientists have warned that humanity must keep the global temperature rise below 1.5°C to avoid the worst effects of climate change.[2] Scientists now expect temperatures to rise as much as 4°C by the end of the century.[3] Climate science attributes this warming primarily to human-driven increases in atmospheric greenhouse gases.[4] Because of the buildup of greenhouse gases, experts believe the Earth system now absorbs a small amount of energy that used to flow out into space.[5]

Climate engineering, sometimes called "geoengineering," is: "the deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming."[6] Experts broadly categorize climate engineering into two main approaches: carbon dioxide removal and solar radiation management ("SRM").[7] SRM, also known as "albedo modification," can address this energy imbalance through small perturbations in the atmosphere that would have immediate and profound effects on the globe.[8]

Stratospheric aerosol injection ("SAI"), the most commonly proposed and most controversial SRM technique, mimics the natural cooling effect of volcanoes by spreading sulfurous particles in the stratosphere.[9] Scholars and commentators widely regard SAI as uniquely polarizing because it promises rapid cooling while raising profound scientific, ethical, and governance concerns.[10]

SAI methods are inexpensive when compared to the economic burden of decarbonizing the globe, and technologically accessible. Nevertheless, SAI is a

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1. *Copernicus: 2024 Is the First Year to Exceed 1.5°C Above Pre-Industrial Level*, COPERNICUS (Jan. 10, 2025), https://climate.copernicus.eu/copernicus-2024-first-year-exceed-15degc-above-pre-industrial-level.

2. James Ashworth, *Climate Change Set to Breach 1.5°C Limit for the First Time by 2027*, NAT. HIST. MUSEUM (May 17, 2023), https://www.nhm.ac.uk/discover/news/2023/may/climate-change-set-breach-limit-for-first-time-by-2027.html.

3. David Gelles, *Can We Engineer Our Way Out of the Climate Crisis?*, N.Y. TIMES (Sep. 30, 2024), https://www.nytimes.com/2024/03/31/climate/climate-change-carbon-capture-ccs.html.

4. OLIVER MORTON, THE PLANET REMADE: HOW GEOENGINEERING COULD CHANGE THE WORLD 2 (2015) ("In 1750, before the industrial revolution, the carbon-dioxide level was 280 parts per million. In 1950, when the great global boom of the second half of the twentieth century was taking off, it was about 310 parts per million. Today it is 400 parts per million. The bulk of that change has been due to the burning of fossil fuels.").

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

6. Michael B. Gerrard, *Introduction and Overview*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL, *supra* note 5, at 1, 2 (citation omitted).

7. *Id.*

8. *Id.*

9. Kintisch, *supra* note 5, at 29.

10. David Gelles, *This Scientist Has a Risky Plan to Cool Earth. There's Growing Interest.*, N.Y. TIMES (Oct. 31, 2024), https://www.nytimes.com/2024/08/01/climate/david-keith-solar-geoengineering.html.

massive endeavor. Latest cost estimates dispel earlier fears that a single wealthy individual, terrorist group, NGO, or small state can unilaterally deploy SAI on a scale large enough to materially affect the global temperature without the participation or consent of others.[11] Even so, experts warn that misguided or desperate actors may undertake SAI as a form of rogue or provocative political action, intended to signal intent, shape norms, or force international response rather than to alter the climate itself.[12] In fact, a Silicon Valley startup, Make Sunsets, has already drawn attention for commercializing SAI by "using balloons to launch reflective clouds into the stratosphere" and selling so-called, "cooling credits."[13]

The existing governance of SAI deployment in the United States contains significant gaps, effectively creating a free-for-all system for many private-sector SAI deployments. Given SAI's political sensitivity and potential environmental dangers, many critics call for an outright ban.[14] Recognizing the danger posed by SAI and the danger posed by climate inaction, this Note rejects both extremes, instead providing a model for regulatory reform. Although Congress could influence climate engineering using tools such as liability shields, accelerated patent examination, or a comprehensive statutory scheme, this Note instead focuses on regulatory reform under existing statutory authority, which offers a more practical and immediate path forward.

On April 15, 2025, the Environmental Protection Agency ("EPA") unexpectedly announced that its Office of Air and Radiation submitted a demand for information to Make Sunsets, a start-up company engaged in private-sector SAI deployments.[15] EPA administrator Zeldin's accompanying statement struck a political, if not conspiratorial, tone, but signaled the Trump administration's interest in leveraging existing statutes to address SAI. [16] The Trump Administration's invocation of the Clean Air Act ("CAA") suggests an improvised interpretation of existing environmental law because it overlooks the more directly applicable Weather Modification Reporting Act of 1972 ("WMRA"), which explicitly addresses activities intended to modify the weather or climate.

This Note does not directly respond to the Administration's reliance on the EPA and the CAA. Rather, this Note argues that the National Oceanic and Atmospheric Administration ("NOAA") already possesses sufficient statutory

11. Wake Smith & Claire Henly, *Updated and Outdated Reservations About Research Into Stratospheric Aerosol Injection*, 164 CLIMATIC CHANGE 39, at 4, 9 (2021).

12. *Id*.

13. *FAQ*, MAKE SUNSETS, https://makesunsets.com/pages/new-faq (last visited Apr. 19, 2025).

14. *See infra* Part.I.

15. Press Release, U.S. Env't Prot. Agency, EPA Demands Answers from Unregulated Geoengineering Start-Up Launching Sulfur Dioxide into the Air (Apr. 15, 2025), https://www.epa.gov/newsreleases/epa-demands-answers-unregulated-geoengineering-start-launching-sulfur-dioxide-air.

16. *See id.* ("The idea that individuals, *supported by venture capitalists*, are putting criteria air pollutants into the air to sell 'cooling' credits shows how *climate extremism* has overtaken common sense." (emphasis added)).

authority under the Weather Modification Reporting Act of 1972 ("WMRA") to meaningfully regulate SAI by establishing a comprehensive, tiered regulatory framework.

Part I surveys SAI–its historical development, ongoing efforts, potential risks and benefits, and latest cost estimates. Part II contemplates a hypothetical private-sector SAI deployment based on latest cost estimates, surveys existing federal and state laws triggered by the hypothetical SAI program, and illustrates that the current governance structure is inadequate. This Note will not discuss the governance of the hypothetical SAI program under international law. Part III expands upon a March 2024 petition for rulemaking filed with NOAA[17] and argues that NOAA possesses sufficient statutory authority to implement a tiered regulatory framework under the WMRA. This tiered framework classifies SAI deployments as either lower-impact or high-impact, and require public notification for high-impact activities. Using transparency and the deterrent effect that flows from public notification, this proposed framework would fill existing gaps in the regulation of SAI.

I. OVERVIEW OF STRATOSPHERIC AEROSOL INJECTION

A. HISTORICAL ORIGINS OF SAI

Particulate matter is a mixture of solid particles and liquid droplets found in the air.[18] Sulfur aerosols, a type of particulate matter, form through complex chemical reactions, typically between sulfur dioxide, an anthropogenic pollutant released by burning fossil fuels, and water vapor.[19]

Awareness of the cooling effect of particulate matter and sulfur aerosols dates back to observations of volcanic eruptions.[20] The 1883 eruption of Krakatoa displaced more than six cubic miles of earth and ejected matter over twenty-five miles into the atmosphere, causing prolonged worldwide effects.[21] The volcanic cloud of sulfate aerosols, mineral dust, and gases remained lodged in the stratosphere for nearly three years where they reflected sunlight, because rain never reaches that altitude and gravity exerts little pull on such tiny particles.[22] The Krakatoa eruption provided the first reliable before-and-after measurements of solar radiation reaching the Earth's surface.[23] Studies estimate

17. This proposal is inspired by a March 2024 petition for rulemaking filed with NOAA by the Energy & Natural Resources Center at the University of Houston Law Center, the Institute for Responsible Carbon Management with the American University's School of International Service, individual law professors, and environmental practitioners.

18. *Particulate Matter (PM) Basics* (May 30, 2025), https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

19. *Id.*

20. MORTON, *supra* note 4, at 275.

21. Edward J. Larson, *The Red Dawn of Geoengineering: First Step Toward an Effective Governance for Stratospheric Injections*, 14 DUKE L. & TECH. REV. 157, 159 (2016).

22. *Id.* at 160.

23. *Id.*

the worldwide drop in annual temperature from the Krakatoa eruption was over 0.5°C.[24]

In the 1960s, scientists who were convinced there was a link between volcanic eruptions and cooler climates, worried that human activity could produce a comparable cooling effect due to anthropogenic sulfur aerosols and dust released by poor farming practices.[25] Anthropogenic sulfur aerosols indeed contributed enough cooling to counteract some of the effects of greenhouse warming.[26] But from the 1960s onwards, health and safety regulations reduced aerosol emissions from fossil-fuel plants and restricted the use of high-sulfur fuels over concerns for human health and acid rain.[27] Paradoxically, the resulting cleaner skies accelerated global warming because they allowed more solar radiation to reach the Earth's surface. Scientists observed the same trend after an international rule limiting the amount of sulfur dioxide in shipping fuel went into effect in 2020.[28] New research shows that drastic reductions in particulate matter pollution resulting from cleaner shipping fuel accelerated warming, further demonstrating the link between less particulate matter and a warmer climate.[29]

The strength of the cooling-effect of aerosols in the stratosphere, whether natural or anthropogenic, is uncertain.[30] Unlike the greenhouse warming effect, scientists struggle to quantify the effects of aerosols, largely because aerosols vary in size, shape, composition, and effect.[31]

Recognizing these uncertainties in 2020, Congress directed NOAA to lead a multi-year initiative to conduct fundamental research on the stratosphere through the Earth Radiation Budget Program ("ERB").[32] The ERB funds projects with the specific goal of establishing a capability to observe, monitor, and model stratospheric conditions.[33] Continuing this effort, the 2022 Federal Appropriations Act ("the Act"), signed by former President Biden, directs the Office of Science and Technology Policy ("OSTP") to form a cross-agency group with NASA, NOAA, and the Department of Energy.[34] The Act instructs this group to develop a research framework that promotes transparency, public engagement, and risk management for publicly funded groups in solar

24. *Id.* at 161.

25. MORTON, *supra* note 4, at 275–76.

26. *Id.* at 278.

27. *Id.* at 279.

28. David Gelles, *Less Pollution, More Global Warming? Why Cleaner Air Is Heating Up the Planet*, N.Y. TIMES (Nov. 3, 2023), https://www.nytimes.com/2023/11/03/climate/less-pollution-more-global-warming.html.

29. *Id.*

30. MORTON, *supra* note 4, at 279.

31. *Id.*

32. *Earth's Radiation Budget*, https://csl.noaa.gov/research/erb (last visited Apr. 19, 2025).

33. *Id.*

34. James Temple, *The US Government Is Developing a Solar Geoengineering Research Plan*, MIT TECH. REV. (July 1, 2022), https://www.technologyreview.com/2022/07/01/1055324/the-us-government-is-developing-a-solar-geoengineering-research-plan.

engineering research, which includes SAI.[35] Additionally, the Act tasks NOAA with supporting OSTP to develop a five-year plan to define research goals for the field, assess the potential hazards of climate interventions, and evaluate the level of federal investments required to carry out this work.

During President Trump's second term, significant workforce reductions by the so-called "Department of Government Efficiency" ("DOGE") threaten NOAA's effort to conduct fundamental research and model development.[36] Created by President Trump's executive order and led by billionaire Elon Musk, DOGE reduced NOAA's workforce by eleven percent, with plans to reduce staffing by a total of nine-teen percent.[37] Insiders already believe that DOGE cuts will negatively affect hurricane forecasting and storm data collection.[38] Project 2025, the "policy blueprint published by the Heritage Foundation that is echoed in many of the Trump administration's actions," labels NOAA as "one of the main drivers of the climate change alarm industry," and calls for the agency to be dismantled and its functions eliminated or privatized.[39] Given the Trump Administration's apparent willingness to compromise fundamental life-saving operations and hostility toward science,[40] the future of the federal government's investment in SRM or SAI–particularly NOAA's role–faces uncertainty and political vulnerability.

B. MODERN SAI ATTEMPTS

Inadequate models and unknown consequences have not deterred interest, experimentation, and even commercialization of SAI. Russian scientist Mikhail Budyko first proposed this technique in 1974, but Nobel laureate Paul Crutzen legitimized the idea in 2006.[41] In the past two decades, experimental efforts to test SAI have become more prominent, demonstrating both growing interest and the persistent controversies surrounding its potential risks.

35. *Id.*

36. Greg Allen, *DOGE Cuts at NOAA Will Impact Hurricane Forecasting and Data Gathering on Storms*, NPR (Mar. 1, 2025, at 08:32 ET), https://www.npr.org/2025/03/01/nx-s1-5313131/doge-cuts-at-noaa-will-impact-hurricane-forecasting-and-data-gathering-on-storms.

37. Elena Shao & Ashley Wu, *The Federal Work Force Cuts So Far, Agency by Agency*, N.Y. TIMES (May 12, 2025), https://www.nytimes.com/interactive/2025/03/28/us/politics/trump-doge-federal-job-cuts.html; Raymond Zhong, Austyn Gaffney & Christopher Flavelle, *NOAA Said to Be Planning to Shrink Staff by 20 Percent*, N.Y. TIMES (Mar. 10, 2025), https://www.nytimes.com/2025/03/08/climate/noaa-layoffs-trump.html.

38. Allen, *supra* note 36; Zhong et al., *supra* note 37.

39. Zhong et al., s*upra* note 37.

40. Dharna Noor, *Trump Continues to Deny Climate Crisis as He Visits Hurricane-Ravaged Georgia*, GUARDIAN (Oct. 1, 2024, at 15:49 ET), https://www.theguardian.com/us-news/2024/oct/01/trump-visits-georgia-denies-climate-crisis-after-hurricane-helene.

41. Kintisch, *supra* note 5, at 29.

Early investigations, such as a 2009 Russian experiment using helicopters to study aerosol formation in the lower troposphere,[42] preceded more ambitious proposals such as the SPICE Project and SCoPEx.[43]

Established in 2010, SPICE was a three-and-a-half year collaboration between the University of Bristol, the University of Cambridge, the University of Oxford, and the University of Edinburgh.[44] The SPICE Project ultimately cancelled its proposed field test, with its leader citing the absence of international agreement on how such research should proceed, notwithstanding their view that the experiment posed minimal environmental risks.

SCoPEX, led by then-Harvard Professor David Keith,[45] with the partial financial backing of Bill Gates,[46] aimed to release small amounts of mineral dust at an altitude greater than twelve miles and observe the dust's behavior as it floated in the stratosphere.[47] Dr. Keith planned a test, possibly over Arizona, in 2018.[48] But when details of the plan became public the Hands Off Mother Earth! Alliance ("HOME"), a group led by Indigenous people, understandably objected and issued a manifesto calling for a "ban on [climate engineering] field experiments and deployments."[49] Three years later, in 2021, Dr. Keith and the Harvard team attempted to conduct the experiment in Sweden.[50] Before the experiment could take place, an international coalition of Indigenous people, led by the Saami Council, protested and successfully halted the project.[51] The Saami Council, like HOME, is adamantly opposed to solar radiation management, especially stratospheric aerosol injection.[52] Swedish climate activist Greta Thunberg praised the effort to halt the project, saying "[n]ature is doing everything it can; it's screaming at us to back off, to stop - and we are doing the exact opposite."[53]

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42. Yu. A. Izrael et. al., *Field Studies of a Geo-Engineering Method of Maintaining a Modern Climate with Aerosol Particles*, 34 RUSSIAN METEOROLOGY & HYDROLOGY, 635, 635–38 (2009).

43. *SCoPEx: Stratospheric Controlled Perturbation Experiment*, https://www.keutschgroup.com/scopex (last visited Apr. 19, 2025); *Aims and Background*, http://www.spice.ac.uk/about-us/aims-and-background (last visited Apr. 19, 2025).

44. *Aims and Background*, *supra* note 43.

45. *SCoPEx: Stratospheric Controlled Perturbation Experiment*, *supra* note 43; Gelles, *supra* note 10.

46. Ariel Cohen, *A Bill Gates Venture Aims to Spray Dust into the Atmosphere to Block the Sun. What Could Go Wrong?*, FORBES (Jan. 11, 2021, at 08:43 ET), https://www.forbes.com/sites/arielcohen/2021/01/11/bill-gates-backed-climate-solution-gains-traction-but-concerns-linger.

47. Gelles, *supra* note 10.

48. *Id.*

49. *Hands Off Mother Earth! Manifesto Against Geoengineering*, INDIGENOUS ENV'T NETWORK 2 (Oct. 2018), https://www.ienearth.org/wp-content/uploads/2018/10/EN-HOME-Manifesto-final-Oct2018.pdf.

50. Gelles, *supra* note 10; Alister Doyle, *Indigenous Peoples Urge Harvard to Scrap Solar Geoengineering Project*, REUTERS (June 9, 2021), https://www.reuters.com/article/idUSKCN2DL2N2.

51. Gelles, *supra* note 10; Doyle, *supra* note 50.

52. Letter from Christina Henriksen, President, Saami Council, Johanna Sandahl, President, Swedish Society for Nature Conservation, Mikael Sundström, Chairperson, Friends of the Earth Sweden, Isadora Wronski, Programme Manager, Greenpeace Sweden, to Members of the SCoPEx Advisory Comm. (Feb. 24, 2021), https://static1.squarespace.com/static/5dfb35a66f00d54ab0729b75/t/603e2167a9c0b96ffb027c8d/1614684519754/Letter+to+Scopex+Advisory+Committee+24+February.pdf.

53. Doyle, *supra* note 50.

One does not need to imagine an aspiring climate engineer who resists public pressure or embraces criticism; such actors already exist. Make Sunsets, a small Silicon Valley start-up, animated by the "move fast and break things" credo, is "unbothered by the criticism that [they have] gone rogue, believing the moment calls for immediate, drastic action."[54] The company sells "cooling credits," their unvalidated equivalent of a carbon credit.[55] Make Sunsets has launched weather balloons containing small amounts of sulfur dioxide from Northern California, Nevada, and Baja California, Mexico, that subsequently exploded at high altitudes to release their sulfates.[56] Make Sunsets' actions sparked controversy and led the Mexican Federal Government to ban this type of solar climate engineering.[57]

C. RISKS AND BENEFITS OF SAI

The risks of SAI, though poorly understood, should not be dismissed lightly. First, SAI does not reduce greenhouse gas emissions or their levels in the atmosphere,[58] and thus it does not address ocean acidification.[59] Ocean acidification is the ongoing decrease in the pH of the Earth's oceans, primarily caused by the absorption of excess carbon dioxide from the atmosphere, which already harms marine ecosystems and inflicts an estimated economic impact of $270 million annually in the United States.[60]

Second, SAI may disrupt regional weather patterns by causing droughts in some places and extreme precipitation in others.[61] Like the 1883 eruption of Krakatoa, the 1991 eruption of Mount Pinatubo in the Philippines injected twenty million tons of sulfur dioxide into the atmosphere, which decreased the amount of sunlight absorbed and lowered global average temperatures about 0.3°C for a period of three years. Floods along the Mississippi River and drought in the Sahel region of Africa may be attributable to climatic shifts caused by the Pinatubo eruption.[62]

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54. David Gelles, *Silicon Valley Renegades Pollute the Sky to Save the Planet*, N.Y. TIMES (Sep. 30, 2024), https://www.nytimes.com/2024/09/25/climate/rogue-solar-geoengineering.html.

55. *Id.*

56. *Id.*; Catherine Clifford, *After Mexican Government Cracked Down on Solar Geoengineering, Startup Lets off Balloons in Nevada*, CNBC (Feb. 22, 2023, at 5:12 ET), https://www.cnbc.com/2023/02/22/solar-geoengineering-startup-make-sunsets-lets-off-balloons-in-nevada.html.

57. Cassandra Garrison, *Insight: How Two Weather Balloons Led Mexico to Ban Solar Geoengineering*, REUTERS (Mar. 27, 2023, at 13:02 PT), https://www.reuters.com/business/environment/how-two-weather-balloons-led-mexico-ban-solar-geoengineering-2023-03-27.

58. However, it is worth noting that several studies suggest that SAI's global dimming–decreasing the amount of solar radiation that reaches the surface of the earth, through SAI–would actually increase the photosynthetic activity of plants and thereby help reduce up to 4.4 million tons of carbon dioxide from the atmosphere annually. Kintisch, *supra* note 5, at 32.

59. Gerrard, *supra* note 6, at 3.

60. Perrin Ireland & Shelia Hu, *Ocean Acidification: What You Need to Know*, https://www.nrdc.org/stories/ocean-acidification-what-you-need-know#communities (last visited Apr. 19, 2025).

61. Gerrard, *supra* note 6, at 3.

62. *Id.*

Third, simulated ozone changes from SAI are unpredictable and highly scenario and model dependent.[63] Stratospheric ozone protects biological life from harmful ultraviolet radiation.[64] After the Pinatubo eruption, for example, total ozone in tropical and temperate latitudes declined by four percent.[65] On the other hand, some scientists believe that stratospheric aerosols may scatter ultraviolet rays, thereby decreasing the harmful effects on biological life.[66] Current research seems to indicate that the composition of the aerosol and the location and season of its release could avoid these harmful ozone depleting consequences.[67]

Fourth, SAI presents a moral hazard. Science writer and Senior Editor at *The Economist*, Oliver Morton, offers billionaire and airline owner Richard Branson's enthusiasm as proof that some view climate engineering as a get-out-of-jail-free card.[68] In 2009, Branson set up a prize to reward progress in pulling carbon-dioxide from the atmosphere and said, "if we could come up with a [climate engineering answer] . . . [w]e could carry on flying our planes and driving our cars . . . ."[69] However, climate scientist Wake Smith argues that SAI's moral hazard is no greater than traditional adaptation or mitigation strategies such as seawalls to repel rising tides, which also seek to decouple greenhouse gas concentrations from future climate damages.[70]

After considering the parade of negatives associated with SAI, a wholesale ban of stratospheric aerosol injection may seem enticing–until one considers the consequences of *business as usual*. Smith acknowledges SAI raises legitimate concerns but argues that restricting SAI research is the wrong response.[71] He contends that withholding knowledge from future generations is indefensible from the standpoint of intergenerational justice.[72] Future generations will likely inherit a breathtaking carbon "debt" which they will struggle mightily to repay.[73] The present generation should not deprive future generations of tools that may lessen the pain bequeathed to them.[74]

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63. *Climate Intervention and Stratospheric Ozone: Introduction and Results from the 2022 UNEP/WMO Scientific Assessment of Ozone Depletion*, MONTREAL PROTOCOL 45TH OPEN ENDED WORKING GRP. 22 (July 4, 2023), https://ozone.unep.org/system/files/documents/SAP_ClimateInterventionSideEvent_4July2023.pdf [hereinafter *2022 Scientific Assessment of Ozone Depletion*].

64. Kintisch, *supra* note 5, at 32.

65. *Id.*

66. *Id.*

67. *2022 Scientific Assessment of Ozone Depletion*, *supra* note 63, at 12–15, 22; *For Stratospheric Aerosol Injection, All Strategies Are Not Created Equal*, (Nov. 6, 2023), https://csl.noaa.gov/news/2023/390_1107.html.

68. MORTON, *supra* note 4, at 28.

69. *Id.*

70. Smith & Henly, *supra* note 11, at 8.

71. *Id.* at 7.

72. *Id.* at 8.

73. Shinichiro Asayama & Mike Hulme, *Engineering Climate Debate: Temperature Overshoot and Peak-Shaving as Risky Subprime Mortgage Lending*, 19 CLIMATE POL'Y 937, 942–43 (2019).

74. Smith & Henly, *supra* note 11, at 8.

Consider, as well, how Oliver Morton and Princeton University physicist Dr. Robert Socolow posit whether humanity should embrace climate engineering. They contend that imagining a world with at least some limited climate engineering becomes necessary if one accepts the following two premises: first, that climate change is a risk that warrants action; and second, that ridding humanity of its fossil fuel dependency is too slow.[75]

No serious observer denies the reality of climate change–the onslaught of extreme weather events has rendered it indisputable.[76] Climate models predict that within thirty to fifty years, portions of the United States (such as Arkansas, Missouri, and Iowa) may exceed the wet bulb temperature limits for humans to survive without technological intervention.[77] Experts warn that we stand on the precipice of a runaway climate catastrophe.[78] Yet global carbon emissions from fossil fuels in 2024 reached a record high,[79] and in 2025 President Trump pledged to cut oil prices and declared he will "drill, baby, drill."[80] A range of institutions have begun rethinking climate policy, including the Council on Foreign Relations whose new approach to climate policy calls for "climate realism" and embraces climate engineering.[81]

Finally, scholarly attention in SAI continues to accelerate rapidly.[82] SAI is neither a secret nor theoretical, raises urgent questions of governance, and demands a coherent regulatory response.

II. REGULATING STRATOSPHERIC AEROSOL INJECTION UNDER U.S. LAW

To ground the analysis of the U.S. governance framework of SAI, this Part focuses on the most likely form that private-sector SAI would take: a domestic

75. David Keith, *A Case for Climate Engineering*, 43 SCI. & PUB. POL'Y 873, 874 (2016); MORTON, *supra* note 4.

76. John Letzing, *Climate Action: Is Climate Denialism Dead?* (Aug. 15, 2022), https://www.weforum.org/stories/2022/08/is-climate-denialism-dead.

77. *Too Hot to Handle: How Climate Change May Make Some Places Too Hot to Live*, NASA SCI. (Mar. 9, 2022), https://science.nasa.gov/earth/climate-change/too-hot-to-handle-how-climate-change-may-make-some-places-too-hot-to-live.

78. *Climate Scientists Warn We're on the Precipice of Disastrous Tipping Points*,' CBC RADIO (Nov. 29, 2019, at 13:22 PT), https://www.cbc.ca/radio/quirks/nov-30-tipping-into-climate-catastrophe-blue-whale-heartbeat-thinking-twice-on-fake-news-and-more-1.5377120/climate-scientists-warn-we-re-on-the-precipice-of-disastrous-tipping-points-1.5377195.

79. *Record Carbon Emissions Highlight Urgency of Global Greenhouse Gas Watch* (Nov. 19, 2024), https://wmo.int/media/news/record-carbon-emissions-highlight-urgency-of-global-greenhouse-gas-watch.

80. Oliver Milman & Dharna Noor, *Trump's 'Drill, Baby, Drill' Agenda Could Keep the World Hooked on Oil and Gas*, GUARDIAN (Mar. 12, 2024), https://www.theguardian.com/us-news/2025/mar/12/trump-fossil-fuels-oil-and-gas.

81. Varun Sivaram, *We Need a Fresh Approach to Climate Policy: It's Time for Climate Realism*, COUNCIL FOREIGN REL. (Apr. 7, 2025, at 00:06 ET), https://www.cfr.org/articles/we-need-fresh-approach-climate-policy-its-time-climate-realism ("The United States should elevate [averting the worst impacts of climate change] as a top national security priority–on the level of averting nuclear war and engaging in great-power competition with China. The most plausible route to averting the worst impacts of climate change is geoengineering.").

82. Smith & Henly, *supra* note 11, at 8.

project that uses aircraft to disperse sulfate aerosols into the stratosphere (the "hypothetical SAI project").

While an earlier analysis by Aurora Flight Sciences (a Boeing subsidiary) suggested global SAI is economically feasible even for small countries or private actors by modifying existing aircraft,[83] recent research rebuts this claim.[84] In a recent study, Wake Smith, a former airline executive and Lecturer at the Yale School of Environment,[85] concludes that no existing aircraft can reliably and economically disperse sufficient quantities of sulfates into the stratosphere, and that only a subset of wealthy nations could feasibly deploy a globally impactful SAI deployment through the year 2100.[86] Smith's total estimate for a globally significant SAI deployment, which includes the design of new aircraft, ranges from $250 billion to nearly $2.5 trillion, with an annual budget in the year 2100 between $7 billion and $72 billion (all in 2020 USD).[87] Expenditures of this magnitude would quickly wipe out individual fortunes and fully consume the annual military budgets of all but 15 countries.[88]

Nonetheless, despite these updated findings, Smith warns of a realistic possibility of "unilateral sub-scale deployment."[89] These deployments might involve smaller quantities of aerosols dispersed at insufficient altitudes to meaningfully affect global climate (or, perhaps, with the aim of affecting regional climate).[90] Although such a strategy would not, by itself, reverse climate change, it would accelerate SAI's emergence onto the global stage. Make Sunsets arguably fits this definition.[91]

As the climate gets hotter and society gets more desperate, one can imagine individuals or companies with greater resources deciding to deploy SAI. Thus, the rest of this Part will examine federal environmental statutes most likely to apply to this hypothetical SAI project. A private-sector SAI project utilizing aircraft to deploy sulfate aerosols escapes, avoids, or can be configured to avoid all meaningful regulation under the National Environmental Policy Act, the Weather Modification Reporting Act, the Clean Air Act, the Clean Water Act, and the Endangered Species Act. An effectively unregulated hypothetical SAI project results.

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83. Justin McClellan, David W. Keith & Jay Apt, *Cost Analysis of Stratospheric Albedo Modification Delivery Systems*, Aug. 2012, at 1, 2.

84. Wake Smith & Gernot Wagner, *Stratospheric Aerosol Injection Tactics and Costs in the First 15 Years of Deployment*, ENV'T RES. LETTERS, Nov. 2018, at 1, 1; Wake Smith, *The Cost of Stratospheric Aerosol Injection Through 2100*, ENV'T RES. LETTERS, Oct. 2020, at 1, 4 [hereinafter Smith, *Cost of Stratospheric Aerosol*]; Smith & Henly, *supra* note 11.

85. Wake Smith, Why Geoengineering is Inevitable, Presentation at Mossavar-Rahmani Center for Business & Government (Feb. 6, 2020), https://www.hks.harvard.edu/centers/mrcbg/students/sg/smith.2020.spring.

86. Smith, *Cost of Stratospheric Aerosol*, *supra* note 84, at 3–4.

87. *Id.* at 2.

88. *Id.* at 11.

89. Smith & Henly, *supra* note 11, at 9.

90. *Id.*

91. *See supra* Part.I.

A. NEPA AND STATE COUNTERPARTS TO NEPA

The National Environmental Policy Act ("NEPA") is a federal procedural statute triggered by "major Federal actions significantly affecting the quality of the human environment."[92] SAI, if deployed by the federal government, would certainly implicate NEPA. On its face, NEPA seems to only apply to projects undertaken by the federal government.[93] Nevertheless, a private-sector deployment of SAI may trigger NEPA, because "major federal actions" include not only activities directly undertaken by the federal government, but also activities that are "potentially subject to federal control and responsibility."[94] Accordingly, NEPA applies if the private action is approved by a federal permit or regulatory decision, or if the action receives financial assistance through loans or grants.[95]

Once triggered, NEPA requires federal agencies either to find that the SAI program has no significant impact (a Finding of No Significant Impact or "FONSI"), fit it within an existing Categorical Exclusion, or prepare an Environmental Impact Statement ("EIS"). An EIS must describe the environmental impacts of the proposed action, discuss alternative actions, and outline irreversible and irretrievable resource commitments.[96]

Until recently, the Council on Environmental Quality ("CEQ") promulgated NEPA's implementing regulations, which specified the steps an agency must follow in preparing an EIS and guided other agencies in complying with NEPA. But on the first day of his second term, President Trump issued Executive Order 14154, titled "Unleashing American Energy," which upends how agencies will conduct reviews under NEPA.[97] The Executive Order seeks to redefine the CEQ's function from issuing binding regulations to providing guidance, thereby delegating the responsibility of establishing NEPA procedures to individual agencies.[98] Although individual agencies must still comply with NEPA, the process is uncertain and fragmented in the absence of the CEQ. Each

92. 42 U.S.C. § 4332(C) (2018).

93. David J. Hayes & James A. Hourihan, *NEPA Requirements for Private Projects*, 13 B.C. ENV'T AFFS. L. REV. 61, 61 (1985).

94. Albert C. Lin, *US Law*, *in* CLIMATE ENGINEERING AND THE LAW: REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON DIOXIDE REMOVAL, *supra* note 5, at 154, 155; 40 C.F.R. § 1508.18 (2020).

95. 40 C.F.R. § 1508.18(b)(4); *ee* Ka Makani 'O Kohala Ohana Inc. v. Cnty. of Hawai'i Dept. of Water Supply, 295 F.3d 955, 960–61 (9th Cir. 2002) (explaining a degree of decision-making power, authority, or control is needed to render a project a major federal action).

96. 42 U.S.C. § 4332(C) (2026).

97. Exec. Order No. 14154, 90 Fed. Reg. 8353, 8355 (Jan. 20, 2025).

98. *Id.*; Brandon Tuck, Max Etchemendy, Corinne Snow, Audrey Doane & Justine Jia, *President Trump's Executive Orders: Rethinking NEPA Regulations and CEQ's Role in Federal Environmental Reviews* (Feb. 14, 2025), https://www.velaw.com/insights/president-trumps-executive-orders-rethinking-nepa-regulations-and-ceqs-role-in-federal-environmental-reviews.

agency now operates under its own set of NEPA implementing procedures, and some may choose to adopt procedures consistent with CEQ regulations.[99]

The CEQ regulations included scoping the issues, circulating a draft EIS to appropriate agencies and the public, responding to any comments received on the draft, and issuing a final EIS.[100] CEQ regulations "categorically excluded" actions from a detailed environmental analysis when the federal action does not have a significant impact on the human environment.[101] However, "highly controversial" actions or actions that contain "unique or unknown risks" require a full EIS.[102]

Executive Order 14154 responds to longstanding criticism by scholars that triggering NEPA is burdensome.[103] Even the Biden Administration sought to decrease the burden of complying with NEPA by implementing page and time limits to EISs.[104] Nevertheless, a rational actor in charge of the hypothetical SAI project would seek to avoid triggering NEPA.

Two actions are most likely to trigger NEPA in the hypothetical SAI project: accepting federal research funding (through, for example, the Department of Energy, National Science Foundation, or NOAA) or engaging in activities that require federal permitting, such as operating on federal land.[105]

Sixteen states, the District of Columbia, and Puerto Rico have enacted analogs to NEPA.[106] Like NEPA, these state environmental policy acts ("SEPA") generally require state government agencies to analyze the environmental impacts of specified actions.[107] The precise details of SEPAs vary from state to state, as some apply just to state agencies, while others apply to local governments as well.[108]

In states where the scope of SEPAs extend to local government actions, the hypothetical SAI project would almost certainly trigger SEPA obligations

99. Jennifer Jeffers, Jacob E. Aronson & Zachary D. Rego, *The CEQ has No Clothes: The End of CEQ's NEPA Regulations and the Future of NEPA Practice*, ALLEN MATKINS LEGAL ALERTS (Feb. 21, 2025), https://www.allenmatkins.com/real-ideas/the-ceq-has-no-clothes-the-end-of-ceqs-nepa-regulations-and-the-future-of-nepa-practice.html.

100. 40 C.F.R. pts. §§ 1502.1(a), 1503.4(a) (2024).

101. *National Environmental Policy Act Review Process* (Apr. 7, 2026), https://www.epa.gov/nepa/national-environmental-policy-act-review-process.

102. 40 C.F.R. § 1508.27 (2012).

103. *See* Daniel R. Mandelker, *The National Environmental Policy Act: A Review of Its Experience and Problems*, 32 WASH. U. J.L. & POL'Y 293, 296 (2010).

104. Rafe Peterson, Jason A. Hill, Alexandra E. Ward & Maggie P. Pahl, *Seismic Changes in Federal Environmental Reviews: CEQ to Rescind NEPA Regulations*, HOLLAND & KNIGHT ALERT (Feb. 25, 2025), https://www.hklaw.com/en/insights/publications/2025/02/seismic-changes-in-federal-environmental-reviews-ceq-rescinds.

105. *See, e.g.*, *Conducting Science*, https://www.blm.gov/learn/science-in-the-blm/conducting-science (last visited Apr. 12, 2026).

106. *States and Local Jurisdictions with NEPA-like Environmental Review Requirements*, https://ceq.doe.gov/laws-regulations/states.html (last visited Apr. 12, 2026).

107. Lin, *supra* note 94, at 158.

108. *Id.*

because they would need local government permits.[109] In contrast with NEPA, some SEPAs, such as the California Environmental Quality Act ("CEQA"), may prohibit projects based on their environmental impacts.[110] Thus, a rational private entity that seeks to limit its SEPA obligations could simply conduct its operations in any one of the thirty-four states that do not have a SEPA.

B. WEATHER MODIFICATION REPORTING ACT AND STATE REPORTING ACTS

Congress enacted the Weather Modification Reporting Act ("WMRA") of 1972 with the goal of ensuring transparency and federal oversight over cloud-seeding projects and other short-term weather modification techniques.[111] Whereas NEPA applies only to activities with non-trivial federal involvement, the WMRA applies to both private and public entities "engag[ing] or attempt[ing] to engage, in any weather modification activity" to submit a report of their activity (via email) at least ten days prior to and after engaging in such activities to the NOAA.[112] Failure to report results in a fine not exceeding $10,000.[113] NOAA compiles and publishes these reports into a database on a quarterly basis.[114]

The WMRA defines weather modification as "any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere."[115] SAI falls squarely within the WMRA's definition of weather modification, which specifically encompasses "influenc[ing] in any way the natural development cycle of clouds of their environment," "[m]odifying the solar radiation exchange of the earth or clouds, through the release of gases, dusts, liquids, or aerosols into the atmosphere," and "[m]odifying the characteristics of land or water surfaces by dusting or treating with powders, liquid sprays, dyes, or other materials."[116] Though SAI and SRM fall squarely within the WMRA, NOAA's database of WMRA disclosures does not include any disclosures of self-identified SRM projects.[117]

Unfortunately for the public, or fortunately for the aspiring climate engineer, only minimal obligations flow from WMRA. WMRA only requires a simple disclosure. Even when the proposed project "significantly depart[s] from

109. *See id.* at 159 ("[P]rojects involving new land uses, construction of new buildings, or the release of pollutants may require state or local permits and thus also may trigger SEPA obligations.").

110. Cal. Pub. Res. Code § 21002 (West 2024).

111. Lin, *supra* note 94, at 160.

112. 15 U.S.C. §§ 330a–330b (2022); 15 C.F.R. § 908.4 (2026); *Weather Modification Project Reports*, NOAA, https://library.noaa.gov/weather-climate/weather-modification-project-reports (last visited Apr. 12, 2026) [hereinafter *Weather Modification Project Reports*].

113. 15 U.S.C. § 330(d) (2022).

114. *Weather Modification Project Reports*, *supra* note 112.

115. 15 U.S.C. § 330 (2022).

116. 15 C.F.R. §§ 908.3(a)(1), 908.3(a)(3), 908.3(a)(4) (2018).

117. Petition for Rulemaking to Amend National Oceanographic and Atmospheric Administration's Reporting Regulations Under the Weather Modification Reporting Act 4 (U.S. Dep't of Com. Mar. 12, 2024), https://www.regulations.gov/document/NOAA-OAR-2024-0091-0001 [hereinafter *SAI NOAA Rulemaking Petition*]; *Weather Modification Project Reports*, *supra* note 112.

the practices or procedures generally employed in similar circumstances to avoid danger to persons, property, or the environment," NOAA *may* notify the operator (the party attempting to modify the weather) and state officials and make appropriate *recommendations*.[118]

WMRA's requirements, while minimal, could serve as an important mechanism for tracking and providing notice of SAI activities to the government and public. Part III proposes a novel regulatory framework to address these shortcomings.

Several states have stricter laws governing weather modification.[119] Generally, these laws address licensing and permitting for cloud seeding.[120] Contrast the WMRA with Texas's regulatory scheme, which requires an operator (potential weather modifier) to be licensed and obtain a permit.[121] To obtain a permit, an applicant must provide proof of "the ability to respond in damages for liability that might reasonably result from the operation."[122] Additionally, the applicant must provide the public notice of the planned operations and, upon request by at least twenty-five people, hold a public hearing.[123] The Texas regulatory scheme contains an exemption to these stringent licensing and permitting requirements for research and development conducted by state and federal agencies, institutions of higher education, non-profit research organizations, or testing conducted in a laboratory.[124] Even if an operator is exempt from permitting requirements, Texas requires written reports.[125] Like Texas, California used to employ a license and permit system. However, in 1978, California repealed most provisions of its regulatory framework, retaining only advanced notice requirements.[126] Under current California law, a weather modification operator must provide advanced notice to the state Department of Water Resources, to the public through publication in a newspaper of general circulation, and to the board of supervisors within affected counties.[127]

118. 15 C.F.R. § 908.12(d) (2024).

119. Lin, *supra* note 94, at 161.

120. *Id.* Cloud seeding is a precipitation-inducing weather modification technique that has been around since the 1940s. *See* Frank McDonough, *What is Cloud Seeding?*, https://www.dri.edu/cloud-seeding-program/what-is-cloud-seeding (last visited Jan. 26, 2026); *Making it Snow: A Brief History and Review of the Science Behind Cloud-Seeding* (Mar. 15, 2023), https://www.dri.edu/making-it-snow (explaining that cloud seeding improves a cloud's ability to produce rain or snow by introducing ice nuclei that allow water droplets to form an ice crystal).

121. Lin, *supra* note 94, at 161.

122. TEX. AGRIC. CODE ANN. § 301.114 (West 2003).

123. TEX. AGRIC. CODE ANN. §§ 301.107(b), 301.112 (West 2003).

124. TEX. AGRIC. CODE ANN. § 301.102(a) (West 2003).

125. *Id.* at § 301.102 (b).

126. CAL. WATER CODE §§ 410–411 (West 1984).

127. Manon Simon, *Enhancing the Weather: Governance of Weather Modification Activities in the United States*, 46 WM. & MARY ENV'T L. & POL'Y REV. 149, 169–70 (2021).

This Note does not survey state WMRAs.[128] However, it is foreseeable that a private actor could shop the hypothetical SAI project among jurisdictions and select a state lacking a robust state analog to the WMRA and a SEPA.

C. CLEAN AIR ACT

The Clean Air Act ("CAA"), unlike NEPA or the WMRA, imposes substantive regulations on private-sector conduct. However, the CAA fails to directly regulate the release of particulate matter in an SAI project that uses aircraft to deploy aerosols.

As an initial matter, it remains unclear whether the deliberate release of substances, normally regarded as air pollutants, would constitute air pollution,[129] as the term "air pollution" typically describes the unintentional by-products of industrial, commercial, or individual activity.[130] In contrast, the CAA defines "air pollutant" broadly to mean "any air pollution agent or combination of such agents, including any physical, chemical, biological . . . substance or matter which is emitted into or otherwise enters the ambient air," as well as "any precursors to the formation of any air pollutant."[131] This broad statutory language and Supreme Court precedent argue in favor of classifying stratospheric aerosols as air pollutants, regardless of their location or reason for release.[132]

The hypothetical SAI project evades four regulatory programs under the CAA: (1) Title I regulates air emissions from stationary sources; (2) Title II governs air emissions from mobile sources; (3) Title IV regulates emissions of pollutants that contribute to acid depositions, including sulfur dioxide; and (4) Title VI implements international obligations to regulate ozone-depleting substances.

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128. Avoiding a patchwork of state weather modification laws provides Congress a compelling reason to preempt state weather modification laws by enacting a comprehensive regulatory scheme. Growing interest in criminalizing SRM (and thus SAI) through state legislation provides a greater urgency for Congressional action. *See* Ceri Putman, Julie Vinders, Joe Sonka, Craig Segall & Josh Horton, *A Growing Number of US States Consider Bills to Ban Geoengineering* (Apr. 11, 2025), https://srm360.org/news-reaction/us-states-consider-bills-to-ban-geoengineering ("The first few months of 2025 saw a sharp rise in the number of US states considering proposals to ban solar [radiation management].").

129. Tracy D. Hester, *Remaking the World to Save It: Applying U.S. Environmental Laws to Climate Engineering Projects*, 38 ECOLOGY L.Q. 851, 877, 877 n.113 (2011) ("The Clean Air Act only applies to releases of 'pollutants' that meet statutory and regulatory criteria. 42 U.S.C. § 7602(g). For example, the intentional discharge of chemicals into the air to fight forest fires has not triggered a need for Clean Air Act permits.").

130. *See* Mark Sagoff, *The Principles of Federal Pollution Control Law*, 71 MINN. L. REV. 19, 22 (1986) ("[P]ollution [is] the by-product of ordinary economic activity."); John Copeland Nagle, *The Idea of Pollution*, 43 U.C. DAVIS L. REV. 1, 41–49 (2009) (discussing the contextual nature of pollution); Lin, *supra* note 94, at 175, 211 n.201 ("Generally, deliberate releases of chemical substances – such as aerial pesticides, forest fire suppressants, and rain-making chemicals—have not required CAA permits.").

131. 42 U.S.C. § 7602(g) (2018).

132. Massachusetts v. EPA, 549 U.S. 497, 529–32, 529 n.26 (2007).

1. Title I and the Regulation of Stationary Sources

Under Title I, a stationary source includes "any building, structure, facility, or installation which emits or may emit any air pollutant."[133] Any portion of the critical ground infrastructure used to make or operate a fleet of aircraft designed to release aerosols into the stratosphere constitutes a stationary source.

Title I of the CAA directs the EPA to identify air pollutants that it reasonably anticipates to endanger public health or welfare and to establish national ambient standards for these "criteria pollutants." The hypothetical SAI project would implicate two criteria pollutants for which the EPA sets national ambient standards: particulate matter and sulfur dioxide.[134] The operator would deploy sulfate aerosols, which are precursors to particulate matter, but through unintended chemical reactions, these aerosols will also form sulfur dioxide.[135] More costly and less likely approaches may involve the deployment of particulate matter–also a criteria pollutant– in the form of rutile, anatase, silicon carbide, synthetic diamond, aluminum oxide, zirconium oxide, or calcite.[136] However, Title I does not regulate the deliberate release of these compounds from an aircraft in the stratosphere, because an aircraft is not a stationary source, but rather, it is a mobile source. The EPA may nonetheless regulate emissions arising from the production, storage, or transport of sulfur dioxide, sulfate, and particulate matter because those activities would occur at stationary sources that fall within Title I. Thus, by employing aircraft, the hypothetical SAI project remains largely outside the scope of Title I of the CAA.

2. Title II and the Regulation of Mobile Sources

Title II of the CAA regulates air pollution from mobile sources by empowering federal agencies to regulate both the nature of engines used by mobile sources and to oversee the composition of fuels and fuel additives.[137] Even though its definition of a mobile source includes aircraft,[138] Title II has limited application because the EPA cannot regulate materials released from an aircraft that are not emitted by the engines or contained in their fuel. Experts agree that an aircraft used in an SAI program would not release aerosols through its engine or field. Rather, it would resemble a tanker and release its payload in

133. 42 U.S.C. § 7411(a)(3) (2018) (defining the stationary source for the purposes of CAA Section 111). Lin, *supra* note 94, at 176, 211 n.204.

134. *Criteria Air Pollutants*, https://www.epa.gov/criteria-air-pollutants (last visited Apr. 12, 2026).

135. Philip J. Rasch, Simone Tilmes, Richard P. Turco, Alan Robock, Luke Oman, Chih-Chieh (Jack) Chen, Georgiy L. Stenchikov & Roland R. Garcia, *An Overview of Geoengineering of Climate Using Stratospheric Sulphate Aerosols*, 366 PHIL. TRANSACTIONS ROYAL SOC'Y 4007, 4010–11 (discussing atmospheric chemical reactions involving sulfur species).

136. Smith, *Cost of Stratospheric Aerosol*, *supra* note 84, at 7–8.

137. 42 U.S.C. § 7521(a) (2018).

138. *Clean Air Act Title II—Emissions Standards for Moving Sources, Parts A Through C* (Mar. 30, 2026), https://www.epa.gov/clean-air-act-overview/clean-air-act-title-ii-emission-standards-moving-sources-parts-through-c.

the stratosphere.[139] Thus, Title II would not extend to aircraft designed to release criteria pollutants into the stratosphere any more than it applies to general commercial aviation.

3. Title IV and the Regulation of Acid Rain

Title IV of the CAA addresses the problem of acid rain and regulates emissions of sulfur dioxide and nitrogen oxides from fossil fuel-fired electric utility units.[140] Whether a hypothetical program would measurably contribute to acid rain formation depends on multiple facts, such as the aerosol released and the scale of the project. According to Wake Smith's most recent study, releasing sulfate aerosols that would measurably increase acid rain costs less than alternatives that would not increase acid rain.[141] However, since Title IV, in its current form, applies only to fossil fuel-fired electric utility units, the hypothetical SAI project would escape regulation under Title IV of the CAA, even if the project releases sulfur dioxide or sulfate aerosols directly into the stratosphere.

4. Title VI and the Regulation of Ozone Depleting Substances

Title VI authorizes the EPA to regulate ozone-depleting substances and identify additional substances that cause or contribute significantly to harmful effects on stratospheric ozone.[142] The Vienna Convention for the Protection of the Ozone Layer of 1985 and its Montreal Protocol of 1987 seek to protect the stratospheric ozone layer.[143] The Montreal Protocol phases out or reduces the production and consumption of stratospheric ozone-depleting substances. Title VI of the CAA is the Montreal Protocol's domestic counterpart.[144]

Stratospheric sulfur aerosols are catalysts for chemical reactions that deplete ozone and reduce ozone levels in the stratosphere, a well-documented concern about SAI use.[145] However, different injection strategies, including location, timing, and material, change the effectiveness of SAI and its overall effects on stratospheric ozone.[146] The latest Scientific Assessment of Ozone Depletion, published by NOAA in 2022, looked at SAI using aerosols other than sulfates and states that "the injection of aerosols other than sulfate is expected to change the effects on ozone via associated changes in heterogeneous

139. Smith, *Cost of Stratospheric Aerosol*, *supra* note 84, at 2.

140. 42 U.S.C. § 7651(b) (2018) ("The purpose of this subchapter is to reduce . . . air pollution and other adverse impacts of energy production and use."); 42 U.S.C. § 7651a(15) (2018) ("The term 'unit' means a fossil fuel-fired combustion device.").

141. Smith, *Cost of Stratospheric Aerosol*, *supra* note 84, at 8.

142. 42 U.S.C. § 7671(a) (2018).

143. Gerrard, *supra* note 6, at 13.

144. Lin, *supra* note 94, at 179.

145. *Scientific Assessment of Ozone Depletion: 2022 Executive Summary*, https://csl.noaa.gov/assessments/ozone/2022/executivesummary (last visited Apr. 15, 2026).

146. *Id.*

chemistry, dynamics and transport."[147] Further, the report recognizes that scientists have not performed comprehensive climate model simulations to quantify these effects, and present-day Earth system models may not accurately simulate SAI's effects on ozone.[148]

Title VI does not currently list either stratospheric sulfur aerosols or the aerosols examined in Wake Smith's recent study as ozone-depleting substances.[149] If the EPA finds that these substances cause or contribute significantly to harmful effects on stratospheric ozone, the agency could add them to the list of regulated substances and establish controls on their production and use. However, given the current regulatory structure, scientific uncertainty, and the absence of relevant substances on EPA's list of ozone-depleting substances, Title VI does not provide a suitable framework for regulating the hypothetical SAI project.

D. ENDANGERED SPECIES ACT

In 1973, a near-unanimous Congress passed the Endangered Species Act ("ESA") to protect fish, wildlife, and plants in the United States threatened with extinction and to preserve their habitats.[150] The ESA reflects a daring attempt to prioritize conservation over economic growth and development.[151] The ESA protects a species only if it is listed as threatened or endangered. Section 4 of the ESA authorizes the federal government to list protected species and to designate critical habitat for such species.[152] Section 7 is conceptually oriented toward the continued survival of the entire species and requires federal agencies to both act and refrain from acting for the benefit of listed species.[153] In contrast with Section 7, Section 9 applies to both public and private actors and protects individual members of listed species from harm by prohibiting the "take" of individuals.

In another Executive Order on the first day of his second term, President Trump declared a "National Energy Emergency," and directed the Interior Secretary to convene the Endangered Species Act Committee to reexamine and presumably delist species.[154] Delisting species would significantly reduce regulatory obligations under both Section 7 and Section 9.

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147. *Id.*

148. *Id.*

149. *Id.*; Smith, *Cost of Stratospheric Aerosol*, *supra* note 84, at 8; *Ozone-Depleting Substances* (Apr. 9, 2026), https://www.epa.gov/ozone-layer-protection/ozone-depleting-substances.

150. Endangered Species Act of 1973, 16 U.S.C. §§ 1531(a)(1), 1531(b).

151. *Id.* § 1531(a)(1).

152. THE STAN. ENV'T L. SOC'Y, THE ENDANGERED SPECIES ACT: A STANFORD ENVIRONMENTAL LAW SOCIETY HANDBOOK 31 (P. Stephanie Easley, Jason P. Holtman, Janine Scancarelli & Brian A. Schmidt eds., 2001).

153. *Id.* at 78.

154. Catrin Einhorn, *Could Trump Use the 'God Squad' to Override Environmental Law?*, N.Y. TIMES (Jan. 28, 2025), https://www.nytimes.com/2025/01/28/climate/trump-endangered-species-god-squad.html.

1. Section 7

Section 7 protects species from activities authorized, funded, or carried out by federal agencies.[155] It requires a federal agency to engage in a consultation process with the U.S. Fish and Wildlife Service or NOAA Fisheries before taking such action.[156] The statute imposes an affirmative duty on federal agencies to "insure that any action . . . is not likely to jeopardize the continued existence of any [listed species] or result in the destruction or adverse modification of [a listed species' critical habitat]."[157]

The agency initiates consultation by asking either the US Fish and Wildlife Service or NOAA Fisheries (collectively the "wildlife agencies") whether listed species are present in the project area.[158] If a listed species may be present and the acting agency finds there is a possibility that a listed species might be affected, the acting agency must engage in formal consultation with the wildlife agencies.[159] This formal consultation results in a determination of whether the action is likely to jeopardize the listed species or adversely alter its critical habitat.[160] The wildlife agencies make a jeopardy determination if the action significantly reduces a listed species' survival or recovery by impacting its reproduction, numbers, or distribution.[161] If the wildlife agencies find no jeopardy determination or adverse modification, then the action can proceed. Otherwise, the wildlife agencies suggest reasonable and prudent alternatives to avoid jeopardy or adverse modification. The acting agency may then proceed under one of the reasonable and prudent alternatives.

Similar to the mechanisms used to avoid triggering NEPA, a private actor may design and fund the hypothetical SAI project in a way that avoids triggering Section 7.[162] By operating outside of federal lands and relying entirely on private funding, the hypothetical SAI project could avoid triggering Section 7 obligations because it is no longer an action authorized, funded, or carried out by a federal agency.

2. Section 9

Section 9 of the ESA prohibits any person, including private actors, from "taking" a listed species.[163] The statute defines a "take" broadly to include "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to

155. THE STAN. ENV'T L. SOC'Y, *supra* note 152, at 79.
156. Lin, *supra* note 94, at 160.
157. Endangered Species Act of 1973, 16 U.S.C. § 1536(a)(2).
158. *Id.* § 1536(c).
159. *Id.*
160. *Id.*
161. 50 C.F.R. § 402.14(g)(4) (2014).
162. *See supra* Subpart.II.A. (explaining that a private actor only triggers NEPA by accepting federal funds and being issued federal permits).
163. 16 U.S.C. § 1538(a)(1).

attempt to engage in any such conduct."[164] Violations of Section 9 can result in civil or criminal penalties, regardless of whether the actor intended to harm the species.[165] The hypothetical SAI project seeks to measurably modify ecosystems and could trigger Section 9's take-prohibition if it affects a large region that includes a habitat for listed species. However, in *Babbit v. Sweet Home Chapter of Communities for a Great Oregon*, the Supreme Court held that a plaintiff must show proximate causation and foreseeability.[166] Given the scientific uncertainty surrounding SAI, proving causation and foreseeability presents a significant hurdle to potential challengers. Moreover, to prove a taking, a plaintiff cannot simply show that a taking may have occurred or might occur in the future.[167] Rather, they must show that a taking already occurred or must be reasonably certain to occur.[168] Thus, enforcement of Section 9 on the hypothetical SAI project would only occur after measurable harm had already occurred.

Neither Section 7 nor Section 9 of the ESA provides a coherent regulatory regime that governs the hypothetical SAI project.

E. CLEAN WATER ACT

The central provision of the Clean Water Act ("CWA") prohibits the "discharge of any pollutant" into waters of the United States by any person without a permit.[169] The CWA imposes criminal and civil penalties.[170] The CWA defines "discharge of a pollutant" as "any addition of any pollutant to navigable waters from any *point source*," or "any addition of any pollutant to the waters of the contiguous zone or the ocean from *any point source other than a vessel or other floating craft*."[171] The CWA defines "point source" as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, [or] well . . . ."[172] An aircraft is not a point source.[173] Therefore, a private-sector SAI deployment using aircraft would not

164. *Id.* § 1532(19).

165. *Id.* § 1538(g).

166. 515 U.S. 687, 700 n.13 (1995) ("The dissent incorrectly asserts that the Secretary's regulation (1) 'dispenses with the foreseeability of harm' and (2) 'fail[s] to require injury to particular animals . . . .'").

167. *See* Pyramid Lake Paiute Tribe of Indians v. U.S. Dep't of Navy, 898 F.2d 1410, 1420 (9th Cir. 1990) (explaining that an activity must cause the harm).

168. *See* Forest Conservation Council v. Rosboro Lumber Co., 50 F.3d 781, 784 (9th Cir. 1995) (explaining that a showing of imminent threat of injury to wildlife suffices).

169. ALLISON RUMSEY, JOEL M. GROSS, ETHAN SHENKMAN & EDWARD MCTIERNAN, CLEAN WATER ACT ESSENTIALS 1–2 (3d ed. 2022).

170. Lin, *supra* note 94, at 179.

171. *Clean Water Act Section 502: General Definitions*, (Feb. 18, 2026), https://www.epa.gov/cwa-404/clean-water-act-section-502-general-definitions.

172. *Id.*

173. In *League of Wilderness Defenders v. Forsgren*, the Ninth Circuit held that aircraft equipped with tanks and spraying apparatus may qualify as point sources when they discharge pollutants directly into navigable waters. 309 F.3d 1181, 1185 (9th Cir. 2002). However, a private-sector SAI deployment would release aerosols into the stratosphere rather than directly into waters of the United States. Because such releases involve indirect, diffuse atmospheric deposition rather than the functional equivalent of a direct discharge, a hypothetical SAI

trigger CWA requirements because dispersal of aerosols from an aircraft does not constitute discharge of a pollutant from a point source, even if the pollutants eventually reach the waters of the United States.

To conclude, the hypothetical SAI project inherently evades nearly all substantive environmental laws at the federal level. A savvy private actor could fashion the project in such a way that avoids triggering federal environmental laws such as NEPA or the ESA. State law creates a patchwork of regulation which allows an actor to carry out their activities in a jurisdiction that provides little oversight.

III. NOAA RULEMAKING UNDER THE WEATHER MODIFICATION REPORTING ACT

As discussed in Part II, the hypothetical SAI project falls squarely within the Weather Modification Reporting Act of 1972 ("WMRA"). However, the WMRA imposes minimal reporting obligations and lacks meaningful oversight. This Part proposes a novel regulatory framework that NOAA could implement under its existing statutory authority pursuant to the WMRA. This Part begins by proposing modifications necessary to clarify the scope of the WMRA and enable such a regulatory scheme. Then, the Part proceeds to describe a proposed regulatory framework—a tiered reporting system that differentiates between high-impact and lower-impact activities. A tiered system allows NOAA to require different levels of disclosure to the public based on the characteristics and potential impacts of a proposed SAI project. NOAA could expand this tiered framework to cover other forms of solar radiation management, such as marine cloud brightening or cirrus cloud thinning. Projects that pose greater environmental or health risks would undergo stringent public notification.

The proposed framework's primary benefit is improved information gathering and dissemination, particularly because the potential harms of SAI depend significantly on the injection strategy. A secondary benefit is deterrence: the tiered approach and varying degrees of public disclosure may discourage private entities–especially those with limited expertise or resources–from pursuing higher-risk projects if doing so requires more burdensome reporting or disclosure to the public.

A. CLARIFYING THE SCOPE OF THE WMRA: WHO THE ACT APPLIES TO

This Note is not the first to call for expanded rulemaking and meaningful regulatory reform under the WMRA.[174] The framework proposed in this Note is

project would not readily trigger CWA permitting requirements, even if some pollutants eventually reach surface waters.

174. Federal environmental law employs tiered frameworks that impose varying degrees of disclosure to the public as a means of influencing public or private behavior. NEPA, for example, categorizes actions based on risk and imposes varying disclosure burdens and compliance with these burdens shape behavior. *See supra* Subpart.II.A.

inspired by a March 2024 petition for rulemaking filed by the Energy & Natural Resources Center at the University of Houston Law Center, the Institute for Responsible Carbon Management with the American University's School of International Service, individual law professors, and environmental practitioners. This proposed framework is consistent with the petition and expands upon it.

1. Include "Solar Radiation Management and Activities Intended to Modify the Climate"

As addressed in Part II, parties engaging in SAI intentionally engage in weather modification activities by attempting to modify the solar radiation exchange of the earth through the release of dust, liquids, gases, or aerosols into the atmosphere.[175] While NOAA's regulations explicitly include SAI as reportable,[176] its weather-modification report database contains just those filed by Make Sunsets, which were filed after the company faced public scrutiny.[177] This suggests the need for NOAA to make its regulations more explicit.[178] NOAA should amend section 908.3(a) to add "including solar radiation management and any activities intended to modify climate."[179]

2. Require Reporting of Small-Scale Experiments

Regulations that provide for exclusions based on the size of the impact misunderstand the incremental and cumulative nature of atmospheric interventions. Currently, WMRA requires reporting whenever a party intends to produce artificial changes in atmospheric dynamics. The WMRA defines "weather modification" as "any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere."[180] This definition arguably excludes non-perturbative, small-scale experiments designed to produce and observe the behavior of chemicals in the atmosphere, as those tests do not intend to produce impactful artificial changes. However, a party seeking to modify the weather (an operator) cannot justify failing to report an experiment based on its scale. For consistency, regulations should require reporting experiments even where the expected cooling (or warming) effect is vanishingly small.

In *Massachusetts v. EPA*, the Supreme Court rejected the argument that incremental contributions do not establish causation in the context of standing. It held that a court may not dismiss even seemingly insignificant contributions resulting from the EPA's decision not to regulate greenhouse gas emissions from

175. *SAI NOAA Rulemaking Petition*, *supra* note 117.
176. *See* 15 C.F.R. §§ 908.3(a)(2), 908.3(b) (2024).
177. *Weather Modification Project Reports*, *supra* note 112.
178. *SAI NOAA Rulemaking Petition*, *supra* note 117.
179. *Id.*
180. 15 U.S.C. § 330(3).

new motor vehicles as inconsequential simply because the individual impacts on the petitioners' injuries are small.[181] Its reasoning underscores a broader principle–that small, individual actions can, collectively, produce significant environmental consequences.

Similarly, the release of even small amounts of aerosols into the atmosphere, intended as experimental SAI activities, certainly produces *some* change in the atmospheric composition, behavior, or dynamics. Therefore, NOAA's regulatory oversight must explicitly include small-scale experiments to fully assess and manage weather modification efforts by public or private entities. The proposed framework should incorporate the Court's reasoning in *Massachusetts* and require reporting of all such activities. Doing so not only strengthens both the public and NOAA's capacity to monitor emerging technologies and the progress of SAI but also remains faithful to the statutory language of the WMRA, which does not carve out a de minimis exception.

Section 908.3(c) includes an exemption for "activities of a purely local nature that can reasonably be expected not to modify the weather outside the area of operation," but NOAA has constrained this exemption solely to lightning deflection, the use of small heat sources to limit frost damage, and religious activities intended to modify the weather. This exemption does *not* include small-scale SAI activities conducted for research or commercial purposes.[182]

Taken together, the WMRA's text, the cumulative nature of atmospheric interventions, and NOAA's narrow construction of existing exemptions support a reporting regime that captures even small-scale SAI experiments.

3. Require Reporting Activities Undertaken Outside the United States that Could Potentially Affect Areas Within the United States' Jurisdiction

The Petition lists three "scenarios of concern" that create a significant danger that private parties may attempt SRM activities while evading the WMRA's broad reporting requirements. These three scenarios include, but are not limited to: (a) actions undertaken in areas subject to U.S. jurisdiction but outside of the United States (as currently defined in the WMRA); (b) actions undertaken outside of the United States by a U.S. citizen or other persons otherwise subject to U.S. jurisdiction; (c) actions undertaken outside of the United States that may reasonably cause effects within the United States. Together, these scenarios illustrate jurisdictional gaps that could allow private actors to conduct activities that undermine WMRA's reporting requirements.

181. *Id.* at 523–24 (2007) (rejecting EPA's argument that regulating greenhouse gas emissions from new motor vehicles contributes so insignificantly to petitioners' injuries that the Agency cannot be hauled into federal court).

182. *SAI NOAA Rulemaking Petition*, *supra* note 117.

a. Actions Undertaken in Areas subject to the U.S. Jurisdiction but Outside of the United States (as Currently Defined in the WMRA)

The Petition states that NOAA defines the United States as "[t]he several States, the District of Columbia, the Commonwealth of Puerto Rico, and any territory or insular possession of the United States,"[183] but the WMRA provides that "[t]he term 'United States' *includes* the several States, the District of Columbia, the Commonwealth of Puerto Rico, and any territory or insular possession of the United States."[184] The U.S. Supreme Court has repeatedly held that "includes" is an open-ended term, especially when one statutory definition uses "includes" and every other definition uses "means"–as with the WMRA.[185] Thus, NOAA should exercise its regulatory jurisdiction over activities in the U.S. Exclusive Economic Zone,[186] on U.S. flagged vessels,[187] and aircraft registered in the United States.[188]

b. Actions Undertaken Outside of the United States by a U.S. Citizen or Other Persons Otherwise Subject to U.S. Jurisdiction

The Petition argues that the United States (and federal agencies carrying out its laws) indisputably have the jurisdictional power to regulate the conduct by U.S. citizens outside of the U.S. territory.[189] It states that "[w]hen Congress chooses to exercise this power, it gives the United States authority over the conduct of those subject to its jurisdiction even when effects of their actions occur outside the United States."[190] Congress's intent is clearly demonstrated in the WMRA's statutory statement of policy, which explicitly refers to its concerns over the international impacts of weather modification activities that could cause harm or conflict.[191] In the context of SAI, international impacts of

183. 15 C.F.R. § 908.1(d) (2024).

184. Pub. L. 92-205, § 1(4), 85 Stat. 736 (1971) (codified as amended at 15 U.S.C. § 330) (emphasis added).

185. *SAI NOAA Rulemaking Petition*, *supra* note 117, at 7; *see* Christopher v. SmithKline Beecham Corp., 567 U.S. 142, 162 (2012)("[T]he definition is introduced with the verb 'includes' instead of 'means.' This word choice is significant because it makes clear that the examples enumerated in the text are intended to be illustrative, not exhaustive."); Burgess v. United States, 553 U.S. 124, 13 n.3 (2008) ("A term whose statutory definition declares what it 'includes' is more susceptible to extension of meaning . . . than where . . . the definition declares what a term 'means.'"); Groman v. Commissioner, 302 U.S. 82, 86 (1937) ("[W]hen an exclusive definition is intended the word 'means' is employed, as in the section we have quoted defining reorganization and in § 112(j), defining the term 'control,' whereas here the word used is 'includes.'").

186. *SAI NOAA Rulemaking Petition*, *supra* note 117, at 7–8.

187. *Id.* at 8.

188. Article 17 of the Convention on International Civil Aviation states "[a]ircraft have the nationality of the State in which they are registered." Convention on International Civil Aviation, art. 17, Dec. 7, 1994, 61 Stat. 1180, 15 U.N.T.S. 295.

189. *SAI NOAA Rulemaking Petition*, 117, at 8–9.

190. *Id.* at 9.

191. Pub. L. 94-490, §§ 2(a)–2(b), 90 Stat. 2359, 2360 (1976) (codified as amended at 15 U.S.C. § 330) ("Weather modification programs may have long-range and unexpected effects on existing climatic patterns *which are not confined by national boundaries* . . . to develop both national *and international* mechanisms designed to minimize conflicts which may arise with respect to the peaceful uses of weather modification . . .

weather modification activities are not hypothetical. SAI, and climate engineering more generally, tend to produce moral and political outrage.[192] Given these risks, it is not only legally permissible but arguably essential for the proposed regulatory framework to reach U.S.-linked activities conducted abroad.

c. Actions Undertaken Outside of the United States that may Reasonably Cause Effects Within the United States

The Petition further argues that NOAA should expand its reporting requirements to include any weather modification activity, undertaken anywhere in the world, which foreseeably or intentionally seeks to cause effects within the United States.[193] As discussed in Part I, Make Sunsets, previously launched at least two weather balloons from Baja California, Mexico, directly south of the U.S.-Mexico Border.[194] SAI could produce transnational effects, and like U.S.-linked activities conducted abroad, these activities have international impacts.

B. PUBLIC DISCLOSURE OF ACTIVITIES

The WMRA provides that, "[a]ll reports, documents, and other information received by the Secretary under the provisions of this chapter shall be made available to the public *to the fullest practicable extent.*"[195] Since Congress passed WMRA in 1972, technological advances have made communicating salient information to the public significantly more practicable.[196]

To implement a tiered framework effectively, NOAA must revise both the timing and requirements for filing an Initial Report, contained under 15 C.F.R. § 908.4(a). This Note outlines the type of information that NOAA should consider when assigning a project to either the high-impact or lower-impact tier. In addition to categorizing the most salient information, the framework should contain limited exceptions that automatically categorize projects into the lower-impact tier.

1. Modifications to the Initial Report

To implement a tiered framework effectively, NOAA would likely need to amend 15 C.F.R. 908.4(a), which governs the requirements for filing an Initial Report. Existing regulations require operators to submit this report within ten

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[and] to integrate the results of existing experience and studies in weather modification activities into model codes and agreements for regulation of domestic *and international* weather modification activities." (emphasis added)).

192. Gelles, *supra* note 10.

193. *SAI NOAA Rulemaking Petition*, *supra* note 117, at 9–10.

194. Garrison, *supra* note 57.

195. 15 U.S.C. § 330(b) (emphasis added).

196. *See supra* note 127 and accompanying text (explaining that California's state weather modification reporting act requires public disclosure in a newspaper of general circulation).

days of their weather modification activities.[197] However, to enable meaningful tier classification, NOAA may need to require the report earlier.[198] This change would allow NOAA to assess the potential risks of a proposed SAI project and assign it to an appropriate reporting tier before deployment begins.[199]

In addition to adjusting the timeline, NOAA should expand the scope of information required because NOAA cannot meaningfully classify projects without detailed information. Specifically, Section 908.4(a) should be amended to require an Initial Report to disclose: (i) the chemical composition, polymorph, and description of the deployed particles; (ii) the mass of deployed particles; (iii) the solar energy that the project will screen, expressed in both W/m2 and total energy for the target area; (iv) a detailed description of the area targeted by the climate intervention action and the identities of properties adjoining the target area that may also incur impacts from the project; (v) the amount of time required for the aerosol to completely disperse to non-detectable levels; (vi) any potential environmental effects of the airborne particles (aside from decreasing solar radiation); (vii) any potential health effects of the airborne particles on human life; (viii) any insurance carried by the project for any potential damage; and (ix) whether the operator did obtain or will seek to obtain a financial benefit for the project's purported effects on solar isolation or climate impacts.[200]

2. Classification Projects as High-Impact or Lower-Impact

This information would allow NOAA to classify each project into a tier based on its potential environmental and health impacts. Tier placement criteria should remain flexible and evolve through periodic of emerging scientific evidence to reflect the state of the art.

Currently, several factors appear especially relevant to the potential harms of SAI. These include the chemical composition and mass of the deployed particles, the geographic location and seasonality of deployment, and the number of injection sites. For instance, non-sulfate particles may pose fewer risks to human health [201] and stratospheric ozone levels. [202] Similarly, dispersing aerosols across multiple injection sites may mitigate adverse effects associated with sharp temperature gradients.[203] NOAA should consider these variables–the chemical composition and mass of the deployed particles, the geographic location and seasonality of deployment, and the number of injection sites–when categorizing an operator's activity to either the high-impact or lower-impact reporting tier.

197. 15 C.F.R. § 908.4(a) (2024).

198. The exact time depends on NOAA staffing and appropriations.

199. NOAA should implement procedures that notify operators of the assigned classification of their actions and offer an opportunity for the operators to amend their plan or appeal NOAA's classification.

200. *See SAI NOAA Rulemaking Petition*, *supra* note 117, at 6.

201. *See* Smith, *Cost of Stratospheric Aerosol*, *supra* note 84, at 5–7.

202. *2022 Scientific Assessment of Ozone Depletion*, *supra* note 63, at 19.

203. *Id.* at 12.

Like the Texas analog of the WMRA, NOAA should grant exceptions for projects conducted by state and federal agencies, institutions of higher education, non-profit research organizations, and laboratory-based testing.[204] Whereas the Texas statute fully exempted such projects from reporting requirements, this proposed framework would instead automatically classify them in the lower-impact tier rather than exclude them entirely. This approach balances NOAA's and the public's interest in gathering information while minimizing regulatory burdens on parties the law should treat favorably. Notably, small-scale field testing by for-profit entities lacking an affiliation with an institution of higher education would not qualify for automatic classification within the lower-impact tier.

3. Public Disclosure for High-Impact Projects

The principal difference that flows from a project's classification as high-impact or lower-impact under the proposed framework is the scope of public disclosure to potentially affected parties and its deterrent effect. NOAA should therefore require all WMRA reports to include both identification and a detailed description of the area targeted by the climate intervention action and the identities of properties adjoining the target area that may also incur impacts from the project.[205] If NOAA revises 15 C.F.R. § 908.4(a) as proposed, this information about be available as soon as an operator files an Initial Report.

SAI, by definition, aims for climate impacts on a global scale, as aerosol particles released at the stratospheric level quickly diffuse horizontally and vertically over wide geographic areas over the course of days or weeks.[206] Some experts have also considered injecting aerosols into the troposphere–the atmospheric layer from the surface up to about ten kilometers—as opposed to the stratosphere.[207] Although these aerosols have a shorter half-life in the atmosphere,[208] they may allow for targeted cooling in response to acute regional weather events, such as extreme heat waves.[209] The proposed regulatory framework should govern these actions, regardless of whether these experiments ultimately succeed. In such circumstances, the framework should require the operator to identify and disclose the span of the target area.

Currently, the operator must file a report that contains a map showing the approximate size and location of the target and control area.[210] Some reports in

204. TEX. AGRIC. CODE ANN. § 301.102 (West 2003).

205. *SAI NOAA Rulemaking Petition*, *supra* note 117, at 5.

206. M. Patrick McCormick, Larry W. Thomason & Charles R. Trepte, *Atmospheric Effects of the Mt. Pinatubo Eruption*, 373 NATURE 399, 399 (1995).

207. Tracy D. Hester, *A Matter of Scale: Regional Climate Engineering and the Shortfalls of Multinational Governance*, 7 CARBON & CLIMATE L. REV. 168, 172 (2013).

208. *Aerosols and Their Importance*, https://earth.gsfc.nasa.gov/climate/data/deep-blue/aerosols?utm_source=chatgpt.com (last visited May 6, 2026).

209. Hester, *A Matter of Scale: Regional Climate Engineering and the Shortfalls of Multinational Governance*, *supra* note 207.

210. 15 C.F.R. § 908.4(a)(5) (2024).

the database (for example, the one filed by Make Sunsets) lack this basic information entirely.[211] Expanding the reporting requirement to include the identities of adjoining property owners would impose a reasonable obligation on operators of all SAI projects. If an operator cannot identify–or simply does not care to know–the individuals living beneath their experiments, regulatory deterrence is warranted. The absence of such basic diligence raises concerns that operators may even deliberately choose to conduct these experiments away from their own land and homes.

The burden of identifying adjoining or otherwise affected landowners in the target area is not particularly high. Numerous digital apps and databases make determining the identity of owners, to the extent that it is available, straightforward, and affordable. Moreover, identifying landowners can also facilitate their notification by NOAA.[212] NOAA should consider a range of notification mechanisms including National Weather Service Alerts, text message, email, or social media.[213]

The tiered framework should reflect the need for transparency, but NOAA must approach public notification with caution. Notification—particularly those issued by the National Weather Service—may amplify public fear and skepticism related to SAI and climate engineering more broadly. Deep skepticism surrounding weather modification, climate change, climate engineering, and the conspiracy theories related to the weaponization of weather already exists.[214] Any regulatory approach must reflect awareness of the unintended consequences that public alerts may generate. Actions that do little more than stoke hysteria could ultimately hinder progress and put the planet at greater risk. Under a tiered framework, only projects classified in the high-impact tier should trigger a notification requirement, where practicable. Projects assigned to the lower-impact tier would not require public notification, thereby avoiding unnecessary administrative burdens and potential panic.

Additionally, NOAA should carefully select the information that it includes in the public notification. Relevant disclosures may include: the chemical composition of the deployed particles, the solar energy that the project will screen, any potential environmental or health effects of the airborne particles to human life, and whether the operator carries insurance for potential damages. Each of these disclosures serves a distinct and important function in promoting public awareness, accountability, and safety. Disclosing the chemical

211. *Weather Modification Project Reports*, *supra* note 112 (search by project name: 2023CASJ-1; 2024CASJ-1; 2025CASJ-1; 2026CASJ-1).

212. The WMRA does not authorize NOAA to impose a public notification requirement upon operators directly, such as the public notification requirement mandated by the California state weather modification reporting act. 15 U.S.C. § 330(b).

213. *SAI NOAA Rulemaking Petition*, *supra* note 117, at 6; *see also Alerts—Text*, https://www.weather.gov/enterprise/sw-alerts-text-1b (last visited Apr. 22, 2026) (summarizing National Weather Service alert systems).

214. Mark Poynting & Marco Silva, *No, Hurricane Milton Was Not 'Engineered,'* BBC (Oct. 10, 2024), https://www.bbc.com/news/articles/cx2lyzw7xwxo.

composition of the deployed particles allows the public to understand the nature of the intervention, since different substances carry different environmental and health risks. Reporting the amount of solar energy that the project may screen informs the public of the intended changes in climate, which influence local conditions such as temperature and precipitation. Sharing information about the potential environmental and health effects enables the public, especially those in vulnerable populations, to assess risks of recreating or being outside. Requiring operators to disclose whether they carry insurance for potential damages serves dual purposes: it signals to the public that the operator may bear financial liability for any harm caused, and it applies political pressure by publicly highlighting whether the operator took appropriate risk-mitigating procedures.

CONCLUSION

As the climate crisis worsens and concerns grow, a previously disfavored tool—climate engineering—appears more attractive. SAI presents a unique governance issue given its affordability and effectiveness coupled with its unknown consequences. Though recent estimates of operating a globally significant SAI program's costs are likely prohibitive for all but a handful of wealthy nations, an individual actor may still operate or attempt to operate a program at a reduced by still substantial scale.

Currently, the federal oversight of SAI is woefully inadequate, with private parties free to experiment or implement so long as they merely report their activities to NOAA, unless the project fortuitously triggers regulation under another federal or state environmental statute. This Note surveyed the history of SAI and explored the U.S. domestic governance of the most likely private-sector SAI program, one that utilizes aircraft to deploy sulfates. This Note also proposed a tiered regulatory framework that improved the information gathering and dissemination by NOAA and classifies activities as high-impact or lower-impact. Under the proposed regulatory framework, NOAA would implement different public disclosure obligations for each tier, which could have a useful deterrent effect on the most controversial activities, without chilling research state and federal agencies, institutions of higher education, or non-profit research organizations. This proposed framework strikes a balance between a ban on SAI implementation or experimentation and the existing regulatory regime that lacks meaningful governance.

SAI represents the most controversial climate engineering technique, but it is only one of many. This Note does not consider international governance of SAI or other climate engineering techniques. Further scholarship should examine the governance structure of all proposed engineering techniques.

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