Solar Geoengineering Research Governance: Proceedings of a Workshop in Brief (2020)

DETAILS

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Proceedings of a Workshop
IN BRIEF

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Solar Geoengineering Research Governance

Proceedings of a Workshop—in Brief

INTRODUCTION

On September 10-11, 2019, the National Academies of Sciences, Engineering, and Medicine's Committee on Developing a Research Agenda and Research Governance Approaches for Climate Intervention Strategies That Reflect Sunlight to Cool Earth hosted a workshop to gather a broad array of information and perspectives on the governance of research for several solar geoengineering (SG) strategies.[1] The workshop followed an earlier workshop on August 7-8, 2019, that had considered the current status of, and future directions for, research on SG strategies. The workshops were convened to inform the committee as it considered potential research needs and structures for governing that research.

During opening remarks, committee chair **Chris Field** (Stanford University) emphasized both the complex nature of SG and the critical importance of public involvement in discussions of SG. Among other things, he said, public opinion plays an important role in the decision to pursue SG research and in whether to potentially deploy SG technologies. Discussions of SG, he said, are particularly challenging because of the complex interactions between science and governance.

THE ROLE OF RESEARCH GOVERNANCE

The workshop began with an overview of the history and aims of research governance by committee member **Hank Greely** (Stanford University). Greely framed his remarks around five questions: (1) What is governance?; (2) What is governance good for?; (3) What is the role of public involvement in research?; (4) What is the relationship between research governance and the governance of an implementation project?; and (5) What makes SG research a special case?

Greely cited a definition of governance used in the 2017 National Academies report *Human Genome Editing: Science, Ethics, and Governance*: "Governance: The process of exercising oversight through traditions (standards of practice) or regulations by which individuals and communities are held accountable. Governance often involves such policy tools as professional standards of practice and codes of conduct, formal guidelines, agreements and treaties, and legislation or other governmental regulation."[2] He emphasized the importance of taking a broad view of governance that encompasses not only mechanisms like laws and treaties but also professional consensus and norms of behavior.

One goal of research governance, Greely said, is to improve research output by increasing the likelihood of getting useful research. But research governance systems can go beyond expert assessments of research quality and risks. Involving the public in discussions about research, he continued, is important because it allows other voices with other ideas to be heard, helps to ensure political legitimacy, and fosters transparency. Research governance, Greely added, will not necessarily affect the governance of any implementation of SG, but as a practical matter, research governance approaches can provide useful models for governing any implementation. Such governance needs to be sure to provide a model for mechanisms for monitoring both planned research and eventual implementation, if any.

Greely concluded his remarks by considering what makes SG research unique. With SG, he said, the stakes are high, and there are high-level competing interests. The climate system is global and immensely complex, and changes to the climate system affect people, businesses, and governments around the world. Currently, he said, there are no international entities,

[1] Specifically, stratospheric aerosol injection, marine cloud brightening, and cirrus cloud thinning. In the context of the workshop, geoengineering was sometimes referred to as climate intervention and solar geoengineering as solar climate engineering.
[2] National Academies of Sciences, Engineering, and Medicine. 2017. *Human Genome Editing: Science, Ethics, and Governance*. Washington, DC: The National Academies Press. P. 299. https://doi.org/10.17226/24623. This definition was itself derived from National Academies of Sciences, Engineering, and Medicine. 2016. *Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values*. Washington, DC: The National Academies Press. P. 23. https://doi.org/10.17226/23405.

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including professional organizations, that can credibly issue guidelines for SG research that will be respected globally. There is also an absence of international agreement on the governance of SG research. Even with international agreement, Greely observed, uniform enforcement of international agreements would be difficult. The reality of climate change means that the governance of SG cannot be considered independent of timescale. He said that as disruptions of the climate system are already occurring, with more severe effects likely coming soon, timescale is an important factor to be considered in the development of methods for governing SG research.

SESSION 1: FOUNDATIONAL QUESTIONS

The first session panelist, **Ted Parson** (UCLA School of Law), stated that results of early research using climate models suggest that well-managed SG might be able to mitigate climate effects with limited direct environmental risks. Nevertheless, he said, the prospect of potential future SG deployment raises such profound governance challenges that even the pursuit of SG research is controversial.

Parson suggested that many observers incorrectly assign risks associated with large-scale outdoor experiments, or even with potential future operational deployments, to smaller scope research. In contrast, he said that the most serious concerns about SG research are less about direct physical risks than about indirect, socio-politically mediated risks (e.g., SG could provide a temptation to ignore climate change or distract from mitigation efforts). While research is extensively governed (e.g., through existing regulatory requirements, funding conditions, and peer review), Parson observed that these provisions are not well suited for consideration of indirect, socio-politically mediated risks, which justify some incremental additional governance provisions for SG research.

Parson noted that there are three possible functions of research governance: to enable, to legitimize, and to control research. He identified several incremental governance needs for SG research and suggested that SG research should be enabled by expanding national or other programs. Doing so, he said, provides an opportunity for internal controls and for informal official-level consultation and coordination. While cautioning against pretending that SG research is mainstream climate science, he argued for moving beyond the present taboo and discussing SG research frankly as a means to promote serious critical scrutiny of SG approaches and their environmental and socio-political implications.

The session's second panelist, **Sheila Jasanoff** (Harvard Kennedy School), began her presentation by enumerating the Oxford Principles for the governance of geoengineering:

- geoengineering should be regulated as a public good
- the public should participate in geoengineering decision-making
- geoengineering research plans should be disclosed
- the results of geoengineering research should be openly published
- there should be an independent assessment of the impacts of geoengineering
- governance mechanisms should be in place before the deployment of SG[3]

These principles are widely known and accepted, Jasanoff said, and many are already embedded in the governance of other fields. She said that the Oxford Principles provide a good starting point for asking the right questions, but she asked workshop attendees to think about the principles in the specific context of SG. In this context, what, she asked, is meant by "public"? How are impacts independently assessed? Where does enforcement responsibility lie? With experiments of a global nature, how is consensus on what is ethical achieved?

Jasanoff suggested that other precedents be considered (e.g., recombinant DNA research, the National Environmental Policy Act [NEPA],[4] stem cell research, etc.) when thinking about principles of governance, about who the decision maker is accountable to (and why), and about the limitations of various governance models (see Table 1).

Jasanoff asked what makes SG research unique, observing that climate change challenges the scales of human organization and self-understanding on multiple dimensions relevant to governance (e.g., space, time, community, and polity). These dimensions have implications for questions such as "who governs" and by what means. She noted that the framing of research questions is itself value laden and that a variety of judgments determines which questions are included in a research agenda. She said that language matters, that the idea of a public is a construct (publics "are made, not found"), and that ideas about proof and demonstration are culturally conditioned.

The session's final panelist, **Stephen Gardiner** (University of Washington), noted that there is widespread agreement that ethical concerns are central to SG decision-making and governance. SG policy, Gardiner argued, involves a range of fundamental ethical concerns that are central to decision-making in both research and deployment, including in the development of research agendas and governance. He noted that the United Nations Framework Convention on Climate Change (UNFCCC) encapsulates several values and ethical concerns that are applicable to SG research, including protections for current and future humankind, ecological values, subsistence values, sustainable development, intergenerational equities,

[3] Rayner, S., C. Redgwell, J. Savulescu, N. Pidgeon, and T. Kruger. 2009. *Memorandum on Draft Principles for the Conduct of Geoengineering Research,* available at http://www.geoengineering.ox.ac.uk/oxfordprinciples/history.
[4] See https://www.epa.gov/nepa/what-national-environmental-policy-act.

TABLE 1 Governance Models and Principles

Precedent	Principle	Accountability	Rationale	Limitations
Asilomar Conference on Recombinant DNA	Self-governance	Scientific peers	Experts understand risks best	Issues framed by scientific leaders; linear model
National Environmental Policy Act	Precaution	Concerned publics	Need democratic buy-in; alternatives	Limited to local project impacts
Product Regulation	Risk reduction	Lawmakers	State is responsible for public welfare	Limited to single products or classes
Human Subjects	Autonomy	Research subjects	Unethical to experiment without consent	Typically individuals and not groups
Stem Cells	Morality	Public ethical norms	Respect societal norms	Easily bypassed without global agreement
Moratorium	Uncertainty	Everyone; humanity	Should not act without reasonable consensus	No progress while science is stopped; "rogue" advantage

SOURCE: Jasanoff presentation, September 10, 2019.

and precaution. SG policy, he said, should be developed holistically and conditionally, within the context of wider global climate policy in which it seeks to play a role.

Gardiner suggested that "benefits and risks" may not be the best way to frame the discussion of SG because "benefits" sound tangible while "risks" sound less certain. He proposed that SG should instead be looked at in terms of "benefits and harms" or "risks and opportunities." He suggested guarding against threats like the temptation for the current generation of the most affluent to "pass the buck" to future, poorer people, as well as the lack of adequate institutions and theories to defend against those temptations. Gardiner proposed moving beyond the Oxford Principles to embrace the Tollgate Principles: framing, authorization, consultation, trust, ethical accountability, technical availability, predictability, protection, respecting general ethical norms, and respecting ecological norms.[5]

SESSION 2: ENGAGEMENT AND REPRESENTATION IN SOLAR GEOENGINEERING RESEARCH

The first session panelist, **Nick Pidgeon** (Cardiff University), discussed his work engaging publics in discussions on emerging technologies. He said that his work engaging in "upstream" dialogues with people about emerging science and technology has demonstrated that such dialogues allow for the incorporation of public values in decisions, improved decision quality, the resolution of conflicts, the establishment of trust and legitimacy, education, and information dissemination. It is critical to recognize, however, that there are many "publics" and many SG technologies—each technology merits its own consideration by the public.

Pidgeon noted that there are multiple approaches that can be used to engage the public. He highlighted the challenges of opening and maintaining deliberative spaces with diverse publics at the national level. The framing of issues, he said, is critical. He suggested that the first aim should be to "open up" around citizen framings of issues, rather than "close down" around top-down questions or solutions. Pidgeon noted that SG already has some strong, problematic prior framing (e.g., framing around fraught terminology like emergency, "naturalness," global warming, and climate "intervention") and that there is no entirely "neutral" information. He advocated the use of advisory panels that include a broad range of stakeholders and for the balancing of technical and ethical information. He observed, based on his own deliberative research on SG, that citizens can arrive at substantive questions and conclusions—both ethical/local-cultural/values-based and technical.

The session's second panelist, **Gary Gardner** (GreenFaith), emphasized that emissions reductions should be a top priority and that a full commitment to emissions reductions should be central to climate strategy. People of religious faith, he said, will say the top priority is emissions reduction because reducing emissions is the right thing to do. For the public, he continued, it is important to frame SG as auxiliary to emissions reductions. Gardner stated that transparency is important, and that any tests related to SG need to be well understood. He advocated for a public clearinghouse of SG research techniques and findings and said that it is important to ensure that countries and sectors most affected by SG, especially low-income regions least responsible for global warming, participate in discussions about research. He advocated for a precautionary approach to the deployment of SG, given that there is currently great uncertainty about the safety of SG. Governance structures, he said, should be in place before testing begins. In the interim, Gardner suggested that there be a moratorium on testing, that legal or regulatory penalties apply to anyone proceeding with testing, and that governance will require public leadership with private involvement subordinate to government control.

[5] The complete text of the Tollgate Principles is available in Gardiner, S. M., and A. Fragniere. 2018. The Tollgate Principles for the Governance of Geoengineering: Moving Beyond the Oxford Principles to an Ethically More Robust Approach. *Ethics, Policy and the Environment* 21(2):143-174.

Session panelist **Holly Buck** (University of California, Los Angeles) discussed the rationale for public engagement in research, drawing from examples in her recent work. Buck suggested that public engagement makes for better science because it helps set research priorities, generate research questions, and advance understanding of the implications of research findings (e.g., elucidate what the outputs of modeling experiments might mean for particular communities). Buck and colleagues conducted a pilot program in Finnish Lapland to learn about regional concerns associated with climate change, as well as community questions and ideas about SG research and governance. While responses in structured interviews revealed local concerns related to tourism, disruptions in seasons, and the health of the reindeer population, the most urgent concerns related to the global impacts of climate change. Buck identified the following takeaways from her research: (1) climate preferences are not obvious to outsiders or easily quantifiable; (2) people have concerns beyond local impacts; and (3) SG technology is imagined as part of a larger social context. Buck concluded that there is a need for a variety of experiments to understand how stakeholders want to be engaged and to understand the role of the public in their engagement.

Wylie Carr (U.S. Fish & Wildlife Service) discussed his work engaging groups in Alaska, the Solomon Islands, and Kenya on climate change. He noted that the people he worked with were already experiencing severe impacts and felt frustrated with the major emitters for not doing more to address climate change. He said that they were willing to consider almost any solution, but that this mindset should not be interpreted as support for SG (they were skeptical that they would benefit from it). Carr noted that their experiences were grounded in past instances wherein Western science and technology reflected an agenda of domination and control. Furthermore, concerns were expressed about who would be in control of research governance. The groups he has worked with wanted:

- early involvement in planning;
- to be given enough information to make informed choices about consent;
- to have not only a seat at the table but also the opportunity to provide meaningful input;
- to have assurances that wealthy nations will be held accountable and that SG should proceed only if wealthy nations showed a stronger commitment to mitigation; and
- SG to be governed as a public good.

Carr suggested that engagement efforts make use of existing organizations already focused on climate change such as the Pacific Community, the African Academy of Sciences, and the Inuit Circumpolar Council. These organizations, he said, can help ensure culturally appropriate engagement that also helps build capacity.

Session panelist **Andy Parker** (Solar Radiation Management Governance Initiative [SRMGI]) observed that the current Global North/Global South disparity over SG research is problematic but not inevitable, and that capacity building is achievable. Parker noted that SRMGI has held engagement workshops in developing countries for a decade. These workshops have consistently found that people are pragmatically open to exploring SG, but that this receptiveness is not indicative of support for proceeding with SG. Parker said that people in both the Global North and the Global South want to know about impacts, control, and unintended consequences. Parker said that while capacity building will be crucial for good international governance decisions, the subject has been largely overlooked. Without their own local SG expertise, developing countries would be relegated to approving or opposing governance proposals designed in wealthy nations, he said, rather than playing an integral role in drafting and negotiation. He suggested that capacity building in the Global South is both desirable and achievable, as has been demonstrated by the DECIMALS research fund that was launched by SRMGI in 2018.[6] DECIMALS was the first international SG research fund, supporting eight research teams across the Global South. Each team works with other teams and with established SG experts to model how SG might affect their region. Parker said that international research collaborations, especially Global North/Global South collaborations, are a crucial first step toward capacity building and suggested that Global North/Global South partnerships should be a part of research programs in wealthy countries.

The session's final panelist, **Drew Endy** (Stanford University), discussed research governance in the context of synthetic biology. Endy discussed his involvement with the development of a report titled *Synthetic Genomics: Options for Governance*.[7] Endy noted that the report did not say what the right governance framework was. Rather, researchers worked with policy experts to develop a comprehensive suite of governance options, which were in turn presented for consideration to those with the responsibility for governing. The work came to the attention of the conservation community, and The Nature Conservancy convened discussions about synthetic biology. Subsequently, the International Union for Conservation of Nature developed "issues briefs" looking at both direct and indirect implications of the technology. Endy noted that a consensus-driven process is hard work but that it presents a process that is publicly defendable. Community building and mutual learning via working together on principles and policy formulation, he said, are worthwhile. Furthermore, good internal leadership is required as periods of inactivity increase the likelihood of unilateral actions.

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[6] See http://www.srmgi.org/decimals-fund.

[7] Garfinkel, M. S., D. Endy, G. L. Epstein, and R. M. Friedman. 2007. Synthetic Genomics: Options for Governance, available at https://www.jcvi.org/sites/default/files/assets/projects/synthetic-genomics-options-for-governance/synthetic-genomics-report.pdf.

SESSION 3: GOVERNING RESEARCH FOR COLLECTIVE BENEFIT: MINIMIZING THE CHANCES OF UNINTENDED IMPACTS WHILE PROMOTING THE COLLECTIVE BENEFIT FOR HUMANKIND AND THE ENVIRONMENT

The first session panelist, **Steve Rayner** (University of Oxford), noted that 10 years after the Royal Society issued its report on geoengineering governance,[8] there is still no tangible form of geoengineering governance because, among other reasons, there is no stable object of governance, the terminology used to describe the proposed technologies remains labile, and technical projects remain theoretical.

Rayner stated that concerns about geoengineering exceptionalism have been exaggerated. He noted similarities between current moral hazard concerns that climate geoengineering will discourage mitigation and earlier concerns that adaptation would diminish mitigation efforts. Despite claims of increasing interest in SG, he said, neither governments nor the private sector have demonstrated a strong demand for SG research.

According to Rayner, a one-size approach to geoengineering technology governance is not appropriate. In his view, any governance regime should have the flexibility to deal with unexpected negative outcomes of technology that become apparent after deployment. He suggested that stratospheric aerosol injection on a global scale would need some type of international agreement, but it is plausible that existing legal laws, frameworks, and institutional arrangements may be sufficient for early-stage geoengineering projects. In Rayner's view, professional standards and codes of conduct could play a role in research governance but have limited appeal to those who are not participants to the process. Rayner said that there is no homogeneous public. Rather, there are competing publics with competing value commitments.

David Santillo (Greenpeace International) began his presentation with a summary of Greenpeace's position on SG. Greenpeace is opposed to SG as a concept because it believes that SG will distract from efforts to reduce greenhouse gas emissions, decarbonize energy and transport systems, and protect natural carbon systems. Greenpeace also believes that SG will lead to unintended and potentially irreversible impacts on other natural systems.

Greenpeace recognizes that, given global proposals to conduct SG research, a global, transparent, and effective regulatory mechanism is needed to ensure that SG research is conducted in a precautionary manner, is not controlled by commercial interests, and is of scientific value, and that consideration is given to the interests of future generations.

Santillo noted that the Climate Action Network, of which Greenpeace is a member, is publishing a position on SG in September 2019 that will support robust adaptation and mitigation as the first-line solution to climate change and state that SG is not a substitute for climate action.[9]

Santillo discussed the London Protocol-London Convention (LP-LC), which focuses on the protection of the marine environment and the scientific benefits from research. The LP-LC provides a tool for assessing proposed activities on a case-by-case basis to determine if proposed activities constitute legitimate scientific research that is not contrary to the aims of the LP-LC.[10]

Professional standards of good scientific conduct should always be applied to SG research, Santillo said, such that there should never be a trade-off between freedom of scientific inquiry and good scientific conduct. Professional standards, he continued, may help identify potential issues, conflicts, and risks but do not alone provide adequate governance of real-world experiments.

Santillo noted that under the Convention on Biological Diversity, no climate-related geoengineering activities that may affect biodiversity should take place until there is an adequate scientific basis on which to justify such activities and a global and transparent regulatory mechanism in place. He said that there are major uncertainties about the science and about geoengineering's effectiveness, costs, and environmental impacts.

Robert Lempert (RAND Corporation) described his experiences working on risk management issues in the context of deep uncertainties. Lempert is participating in an informal mechanism that brings Culver City, California, government officials and community stakeholders together to address issues arising from a large influx of employers and employees into their community. This informal, off-the-record process runs parallel to more formal mechanisms used by local and state jurisdictions for governance. This is a potential model for engaging scientists and stakeholders in a discussion of potential scenarios in parallel with oversight governance of SG, he said. It could also be a mechanism to explore governance with the involved parties.

The next session panelist, **Sikina Jinnah** (University of California, Santa Cruz), addressed how to design a regime for processes and practices of good governance that promotes transparency and fair distribution of benefits, protects vulnerable populations, and amplifies marginalized voices. She cited various principles of good governance, including public participation, transparency, accountability, fairness, and public good.

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[8] See Royal Society, Geoengineering The Climate: Science, Governance and Uncertainty, September 1, 2009, available at https://royalsociety.org/topics-policy/publications/2009/geoengineering-climate.

[9] The Climate Action Network's position statement, "CAN Position: Solar Radiation Modification (SRM), September 2019," was posted on September 12, 2019, at http://www.climatenetwork.org/publication/can-position-solar-radiation-modification-srm-september-2019.

[10] Santillo referenced Santillo, D., and P. Johnson. 2016. How Can Geoengineering Research Be Regulated? *Royal Society of Chemistry Environmental Chemistry Group Bulletin* July 2016:16-18 as a document that outlines the background and history of the LP-LC's position and the possible parallels to SG research governance. The paper is available at http://www.greenpeace.to/greenpeace/wp-content/uploads/2019/09/Santillo-Johnston-2016.pdf.

Jinnah first addressed the question of why SG research should be governed now. She noted that SG governance literature emphasizes the importance of building a governance foundation that fosters public trust, shared norms, and scalable solutions as the research progresses.[11] She also observed that states, scientists, international organizations, sub-states and local government, non-state entities, developing countries, vulnerable communities, and broader publics should be involved in the governance process.[12] Countries can create national research programs and funding streams as well as governance mechanisms.[13] Sub-national and local governments can also play a role, be more nimble than states, and create mechanisms for inclusion of more voices.[14] Jinnah said that there is a particular need to pay attention to developing countries, as they are marginally represented in the current SG research landscape.

Jinnah identified several gaps in the SG research governance literature for participants to consider:

- How do climate intervention technologies fit within a broader portfolio of climate change response?
- How can sub-state and non-state actors play a role in governance?
- What can we learn from the governance of other novel or emerging technologies?
- How should we consider SG politics in developing countries?

Jonathan Pershing (William and Flora Hewlett Foundation) formerly served as the U.S. Department of State Special Envoy for Climate Change, where he was engaged in multi-lateral negotiations. Pershing said that oversight is important for SG research because it has the potential to transform the world's ecosystems. Governance for research activities that have the potential to affect more than a single country or legal jurisdiction is needed in order to enable affected persons to participate in the process. He views SG research as distinct from other emerging technologies because of its potential to alter ecosystems well beyond local areas and because it is of a similar scale to other human activities that have been the subject of global or multi-lateral arrangements (e.g., climate change, ozone depletion, biodiversity loss, and transboundary air pollution). Pershing suggested that the governance of SG research can only be treated as distinct from SG deployment if the research does not lead to consequences outside the jurisdiction where the research is taking place.

Pershing identified the following as critical SG governance gaps: (1) identifying the authority to make go/no-go decisions, (2) establishing linkages between the Global North and the Global South, (3) optimizing representation of the various stakeholders, (4) addressing the interconnectedness of scientific and social issues, and (5) creating durable institutions. Pershing suggested conducting an assessment of current potential institutions that might be appropriate oversight bodies for SG. He said that the United Nations Economic and Social Council might be an appropriate forum for the review process, which should include an analysis of whether the body has legal authority over the activities, who has representation at the institution, whether the institution can assess and monitor the effects of activities, and whether it has mechanisms to manage compliance or adverse impacts.

The Oxford Principles, Pershing said, are a good starting point for governance discussions. He noted that most international agreements use non-binding compliance. This approach may not be effective for SG governance because it takes considerable time to develop a comprehensive international regime. He also noted that overall funding for SG research is modest and that, while philanthropic support for SG research is increasing, the checks and balances in place for federally funded research do not necessarily apply to research exclusively funded by private sources.

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[11] See, e.g., Long, J. C. S., F. Loy, and M. G. Morgan. 2015. Policy: Start Research on Climate Engineering. *Nature News* 518(7537):29. https://doi.org/10.1038/518029a; Lloyd, I. D., and M. Oppenheimer. 2014. On the Design of an International Governance Framework for Geoengineering. *Global Environmental Politics* 14(2):45-63. https://doi.org/10.1162/GLEP_a_00228; and Parson, E. A., and L. N. Ernst. 2013. International Governance of Climate Engineering. *Theoretical Inquiries in Law* 14(1):307-338. https://doi.org/10.1515/til-2013-015.

[12] See, e.g., Chhetri, N., D. Chong, K. Conca, R. Falk, A. Gillespie, A. Gupta, S. Jinnah, P. Kashwan, M. Lahsen, A. Light, C. McKinnon, L. P. Thiele, W. Valdivia, P. Wapner, D. Morrow, C. Turkaly, and S. Nicholson. 2018. *Governing Solar Radiation Management.* Washington, DC: Forum for Climate Engineering Assessment, American University. https://doi.org/10.17606/M6SM17; Hubert, A.-M. 2017. *Code of Conduct for Responsible Geoengineering Research.* Geoengineering Research Governance Project, Interim Report, available at http://www.ce-conference.org/system/files/documents/revised_code_of_conduct_for_geoengineering_research_2017.pdf; Nicholson, S., S. Jinnah, and A. Gillespie. 2018. Solar Radiation Management: A Proposal for Immediate Polycentric Governance. *Climate Policy* 18(3):322-334; Rahman, A. A., P. Artaxo, A. Asrat, and A. Parker. 2018. Developing Countries Must Lead on Solar Geoengineering Research. *Nature* 556(7699):22. https://doi.org/10.1038/d41586-018-03917-8; and Winickoff, D. E., J. A. Flegal, and A. Asrat. 2015. Engaging the Global South on Climate Engineering Research. *Nature Climate Change* 5(7):627-634. https://doi.org/10.1038/nclimate2632.

[13] See, e.g., Ghosh, A. 2018. Environmental Institutions, International Research Programmes, and Lessons for Geoengineering Research. In *Geoengineering Our Climate? Ethics, Politics, and Governance,* edited by J. J. Blackstock and S. Low. London: Routledge. https://doi.org/10.4324/9780203485262-37; Keith, D. W. 2017. Toward a Responsible Solar Geoengineering Research Program. *Issues in Science and Technology* 33(3):71–77; and Stilgoe, J., R. Owen, and P. Macnaghten. 2013. Developing a Framework for Responsible Innovation. *Research Policy* 42(9):1568-1580. https://doi.org/10.1016/j.respol.2013.05.008.

[14] See, e.g., Jinnah, S. 2018. Why Govern Climate Engineering? A Preliminary Framework for Demand-Based Governance. *International Studies Review* 2(2):272-282. https://doi.org/10.1093/isr/viy022.

SESSION 4: PERSPECTIVES ON EXISTING AND POTENTIAL GOVERNANCE FRAMEWORKS FOR GEOENGINEERING RESEARCH

The first session panelist, **Louise Bedsworth** (California Strategic Growth Council), spoke about her work as chair of the newly established Advisory Committee for Harvard University's Stratospheric Controlled Perturbation Experiment (SCoPEx) project.[15] SCoPEx seeks to advance understanding of stratospheric aerosols relevant to SG. The Advisory Committee was established in July 2019 to provide advice on the research and governance of the project to university leadership and the project's principal investigator.

The Advisory Committee's goals, Bedsworth said, are to evaluate the technical and legal soundness of the research and to consider issues of legitimacy, transparency, and replicability. The Advisory Committee is developing a framework that includes peer review, stakeholder engagement, expert engagement, and communications and accessibility. According to Bedsworth, the Advisory Committee plans to develop a set of norms and a process for the committee's work, develop plans to communicate the work of the committee, identify and engage with stakeholders, and determine the scope of peer review and whether it should include stakeholder engagement considerations.

Daniel Bodansky (Arizona State University) provided an overview of existing international norms governing climate interventions. He described existing general governance frameworks for climate intervention with transboundary effects, noting that there is a general duty under customary international law to use due diligence to prevent transboundary harm, to assess activities likely to cause transboundary harm, and to notify potentially affected states. Bodansky noted that the existing framework addresses the transboundary effects of climate intervention but does not prohibit SG research or address broader political and ethical concerns such as moral hazard and slippery slope.[16]

Bodansky noted that it is essential for any future SG governance to address key questions about the function of governance frameworks, participation in the governance process and decision-making, and activities governed. According to Bodansky, considerations in selecting a governance forum include:

- the need for facilitation and support;
- whether the body should be regulatory in nature and have standard setting or permitting authority;
- who has the authority to make decisions and who are the decision makers; and
- whether it has authority to assess, monitor, and oversee activities or enforce obligations globally.

Bodansky described how the type of governance depends on the concerns that need to be addressed and the function of governance (see Table 2).

TABLE 2 Functions of Governance

Concern	Function of Governance	Type(s) of Governance
Insufficient research, given potential need for (or use of) climate intervention (CI)	Address barriers to research (funding, legitimacy, coordination)	Institutions to develop research agenda, promote cooperation on information and cost sharing Transparency/stakeholder involvement to enhance legitimacy
CI immoral, unacceptable	Stop research	Moratorium or ban
Research carried out in risky, irresponsible way	Limit/regulate research	Standard-setting Authorization procedure Oversight Liability and compensation
Insufficient discussion of CI	Provide a forum	Communication/negotiation

SOURCE: Bodansky presentation, September 11, 2019.

Many international institutions, Bodansky noted, issue non-binding decisions, but the United Nations Security Council is the only existing institution with binding legal authority. There are many other steps that international organizations can take short of a moratorium to promote safe, responsible research, he said. These include requiring consultations with affected states, public involvement, requirements for an independent assessment of environmental impacts, and/or publishing the research results.

Bodansky described three functions that could be provided by an international institution: (1) support of and facilitation of research; (2) oversight of research; and (3) decision-making authority over research. Bodansky said that no compensation regime exists for major transboundary harms from climate interventions, and many nation states are unlikely to agree to such a compensation regime.

[15] Additional information on SCoPEX is available at https://projects.iq.harvard.edu/keutschgroup/scopex-governance.
[16] Slippery slope is the idea that pursuing research on SG opens a path that will eventually lead to the deployment of SG.

Tracy Hester (University of Houston Law Center) discussed existing domestic laws that might apply to SG management. He described a network of federal and state environmental, health and safety, and liability laws that provide an ad hoc governance framework for research on SG strategies. Hester noted that federal and state environmental impact assessment laws often provide exemptions for research conducted within a laboratory. He said that while there is no existing research exemption in federal environmental laws that squarely applies to SG research, the concept of a research exemption exists.

NEPA is a procedural statute that requires federal agencies to study and consider the environmental impacts of their activities. An Environmental Impact Statement must be prepared for a major federal action that significantly affects the quality of the human environment. NEPA provides a mechanism for assessing the environmental impacts of research that is federally funded or involves federal action, such as permitting; however, the law does not set out any substantive environmental standards for compliance.

Another relevant but lesser-known domestic statute is the National Weather Modification Policy Act of 1976 (NWMA). The statute requires the filing of a mandatory 10-day notice with the National Oceanic and Atmospheric Administration of weather modification activities. The statute does not distinguish between research and commercial use of weather modification, and the broad definition of weather modification could be interpreted to include SG, although it does exempt small projects designed to have purely local effects.[17] Federal regulations implementing NWMA may require notifications of marine cloud brightening and cirrus cloud modification research.[18]

Hester noted that tort law is a possible avenue to pursue domestic legal challenges to SG. According to Hester, standing can be challenging for plaintiffs, as state laws differ with respect to weather modification permitting regimes, and some state laws may have liability shields.

To some extent, Hester observed, the fragmentary nature of statutes and rules may enable "governance shopping." Individuals may choose which federal or state agency to approach, depending on the desired outcome. He said that a roadmap for attaining consistent interagency coordination might be desirable and suggested that the Coordinated Framework for the Regulation of Biotechnology might be a useful model.

The final session panelist, **Joshua Horton** (Harvard University), discussed issues related to compensation in the context of research governance. Compensation for harm from SG is important, he said, for ethical and moral reasons such as humanitarian obligations and meeting the demands of climate justice. In practice, deployment in the absence of agreement would be costly due to political opposition based on calculations of national interest. Securing these interests would require compensation. According to Horton, among the key risks posed by SG would be climate response damages, in particular regional hydrological changes.

Thus far, tort actions seeking compensation for climate harms have failed because of structural incongruities between tort liability and climate, in particular differing theories of proximate causation. Horton noted that the Paris Agreement rules out liability for loss and damage. He said that risk transfer (insurance) is emerging as a preferred response in the UNFCCC. He cited the example of the $550 million G7 InsuResilience program supporting regional sovereign risk pools.[19] This is an example of a parametric insurance scheme in which payouts are made when a triggering event occurs. Typically, the trigger is an objective parameter or index (e.g., rainfall, wind speed) that crosses a predefined threshold. Causation does not matter for parametric insurance.

A suitably designed sovereign risk pool based on parametric insurance could provide compensation for climate harms from SG deployment or large-scale experiments. In Horton's view, environmental harm from small-scale research would most likely result from accidents. This risk could be addressed by the tort system within the United States and, at the international level, through customary international law or specific treaties, he added.

SESSION 5: LESSONS LEARNED FROM THE GOVERNANCE OF RESEARCH IN OTHER FIELDS

The first session panelist, **R. Alta Charo** (University of Wisconsin–Madison School of Law), began her presentation by reflecting on the distinctive features of the life sciences, noting that the late 20th and early 21st centuries marked a period of rapid advances in life sciences research. She observed that the cross-border nature of life sciences research, the cross-border nature of some applications, and the increasingly decentralized capacity for research and development changes views on appropriate governance. Charo reflected on the choices that might be employed in governance. She noted that these choices include "soft" (e.g., community norms and financial or other incentives) versus "hard" (e.g., formal regulation), "push" (e.g., requirements) versus "pull" (e.g., offering advantages to those who satisfy certain conditions), and "static" (e.g., comprehensive rules to ensure predictability over time) versus "adaptive" (e.g., ongoing assessment and revision of rules in light of growing evidence).

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[17] NWMA defines weather modification as "any activity performed with the intention and expectation of producing changes in precipitation, wind, fog, lightning, and other atmospheric phenomena." See https://www.govtrack.us/congress/bills/94/s3383/text. Implementing regulations define weather modification as "any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere." See 15 CFR Section 908.1. 15 CFR Section 908.3 includes "modifying the solar radiation exchange of the earth or clouds through the release of gases, dusts, liquid or aerosols into the atmosphere" in a list of eight items that, "when conducted as weather modification activities, shall be subject to reporting."

[18] See 15 CFR Section 908.3(a)(1).

[19] See https://www.insuresilience.org.

The second panelist, **Alex Wellerstein** (Stevens Institute of Technology), reflected on the scientific and governance lessons to be learned from nuclear history. Wellerstein observed that nuclear policy and regulations have been driven by fears, including the fear of the Nazi interest in fission, the fear of an uncontrolled arms race, the fear of private ownership of nuclear weapons, the fear of proliferation among U.S. allies, and the fear of an accelerated arms race. He noted that during World War II, even before nuclear weapons were detonated, legislation was being drafted to address nuclear research. Although the U.S. government tried to create a narrative for nuclear power, the success of its policies was mixed, and it ultimately lost the ability to control the narrative. He said that while, in principle, nuclear weapons could have been easy to regulate (by virtue of the small number of actors with resources to build them and the rarified nature of the material involved), that regulation never occurred because nation states have had a great desire to build them.

Lisa Levin (Scripps Institution of Oceanography) noted that deep-ocean science policy challenges have similarities to SG research. She observed that work in the deep sea is an inherently international endeavor because activities are often global in scale and occur in areas beyond national jurisdiction and that there are many unknowns, governance gaps and inefficiencies, sustainability challenges, multi-disciplinary solutions, and a limited number of scientific experts who often lack policy experience. Levin sees deep seabed mining as the closest analog to SG, as it is a nascent industry with unknown environmental impacts, many knowledge and technical gaps, and an area where much investment is needed to support observations, modeling, and infrastructure. Furthermore, as is the case with SG, experimentation can be seen as de facto deployment. Levin highlighted the Deep-Ocean Stewardship Initiative as a potential model for the governance of SG research. The initiative, she said, "seeks to integrate science, technology, policy, law, and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdictions."

Deneb Karentz (University of San Francisco) discussed lessons for science and policy learned from scientific collaborations in Antarctica. Article I of the 1959 Antarctic Treaty stipulated that Antarctica be used for peaceful purposes only, and Article II stated that freedom of scientific investigation should continue. In the United States, federal agencies, such as the National Science Foundation, provide national coordination of science and policy in Antarctica. The United States is a member of both the Scientific Committee on Antarctic Research (SCAR) and the International Arctic Science Committee, multi-national organizations that facilitate international collaboration in polar research. SCAR further provides objective and independent scientific advice to the Antarctic Treaty System and other bodies (such as the Intergovernmental Panel on Climate Change).[20] SCAR activities, Karentz said, are driven by the scientific community. She suggested that:

- a mechanism (similar to the SCAR Horizon Scan) be established to canvas the wider scientific community for ideas on SG;
- partnerships with science organizations like SCAR be established to prioritize research issues, facilitate international collaborations, and establish codes of conduct for research activities; and
- the structure of current effective systems be adopted in the formation of a new framework for global/regional planning for climate mitigation.

The final session panelist, **Stuart Russell** (University of California, Berkeley), discussed the risks and governance of artificial intelligence (AI). Russell stated that, in the standard AI model, humans supply machines with objectives, and the machines are expected to achieve these objectives. According to Russell, the upside of AI has been an enormous increase in the capabilities of civilization, the rise of Everything-as-a-Service (a variety of services and applications accessed on-demand over the Internet as opposed to at a physical site), and a 10-fold increase in world gross domestic product. The downside, he suggested, has been a democracy undermined by "bots," the rise of autonomous weapons, robots replacing humans in the workforce, and the enfeeblement of humanity. Russell asked what measures could be taken to ensure that increasingly intelligent machines (like SG) remain under civilian control. He suggested that AI be rebuilt from the ground up. He advocated for a new model in which humans have the objectives and machines help to achieve them, but the machines may not know the objectives. Russell said to beware of fixed objectives (e.g., develop a planetary temperature control system using SG). He advocated for research on the socio-technical system (e.g., the connection of deployed systems to humanity) and said that research should only be allowed to proceed when high barriers to deployment are in place. Given the presence of conflicting goals and beliefs, he added, deployment should only be explored via conditional contracts.

CONCLUDING ROUNDTABLE DISCUSSION WITH ALL SESSION PANELISTS

The workshop ended with an open discussion among panelists and other workshop participants. Committee chair Chris Field noted that one dominant theme that had emerged during the workshop was that it might be challenging to develop an international treaty on SG because of the time and effort required. Another important theme, he said, was the role of stakeholder engagement in governance environments. Field said that the workshop discussions raised important questions

[20] "The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change." It "was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options." See https://www.ipcc.ch.

about how to best establish a successful governance foundation, about who should be brought into conversations about governance, and about whether existing non-governmental organizations can build necessary governance structures and, if not, whether new governance organizations would be needed.

DISCLAIMER: This Proceedings of a Workshop—in Brief was prepared by **Steven Kendall** and **Anita Eisenstadt** as a factual summary of what occurred at the workshop. The committee's role was limited to planning the event. The statements made are those of the individual workshop participants and do not necessarily represent the views of all participants; the planning committee; the Board on Atmospheric Sciences and Climate; the Committee on Science, Technology, and Law; or the National Academies.

REVIEWERS: To ensure that it meets institutional standards for quality and objectivity, this Proceedings of a Workshop—in Brief was reviewed in draft form by **Tracy Hester,** University of Houston Law Center; **Sikina Jinnah,** University of California, Santa Cruz; **Gary Marchant,** Arizona State University; and **Ambuj D. Sagar,** Indian Institute of Technology Delhi. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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