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Report

Preparing the United States for security and governance in a geoengineering future

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I. Introduction

Imagine the following scenario: it is the year 2035. One large country, dealing with major issues of global warming, decides to take extreme action. The government begins secret deployment of a geoengineering system for pumping large amounts of reflective particles into the air, a technique designed to mimic the cooling effect of a volcanic eruption, only on a much larger scale and over a much longer time horizon. Although such behavior has been discouraged by the international community, research has continued, largely behind closed doors and without real regulation. Now that the climate situation has become more dire, the country has decided that it can no longer afford to wait; they see geoengineering as their only option.

At first, the decision seems wise, as the increase in global temperatures start to level off. But soon other types of anomalous weather begin to appear: unexpected and severe droughts hit countries around the world, disrupting agriculture, and the ozone layer begins to decay rapidly, exposing populations to harmful radiation. Global weather has become politicized—delegates argue at the United Nations over new climate complications allegedly caused by geoengineering, and diplomatic relationships are strained. This new geoengineering crisis escalates when another large country, under the impression it has been severely harmed by the geoengineering, carries out a focused military strike against the geoengineering equipment, a decision supported by other nations who also believe they have been negatively impacted. This development, however, becomes even more devastating, as once the geoengineering stops, global temperatures dramatically rebound to the levels they would have reached on their previous trajectory, prior to the use of geoengineering. The resulting consequences of such a dramatic increase in temperatures are disastrous.

A scenario such as the one above remains unfortunately possible given the current state of global geoengineering policy. As the increasingly severe effects of global warming generate greater interest in geoengineering technologies, the United States must prepare itself for the risks and uncertainties that come along with their potential deployment. Preparedness for such a world will likely be multi-faceted and will likely include improved understanding of how the global climate will change both with or without geoengineering, the ability to detect and monitor geoengineering activity worldwide, an adequate policy roadmap for deterring certain kinds of geoengineering activity and for responding in case of geoengineering deployment by other nations, among other measures.

The U.S. should also make a concerted effort to foster the development of an international governance regime for geoengineering. In the short term, that will involve leveraging existing international fora to legitimately debate geoengineering issues on the international stage while also championing a comprehensive code of conduct for geoengineering research worldwide. In the long run, the U.S. should take the lead on creating a geoengineering-specific international body, one with the appropriate scope and flexibility to deal with the myriad challenges involved while also promoting wide participation.

II. Geoengineering overview and security concerns

We have already begun to see the effects of man-made climate change around the world. As average temperatures climb, droughts become more frequent, storms become more destructive, and sea levels rise, among other harmful effects. The international community has made emissions mitigation its goal to prevent catastrophic levels of climate change, but as nations habitually fall short of targets deemed necessary by climate scientists, the risk of climate emergency heightens.

As a result, conversations around geoengineering have become more frequent. Defined as "the deliberate large-scale manipulation of an environmental process that affects the earth's climate in an attempt to counteract global warming," geoengineering can broadly be divided into two very different subcategories: 1) carbon dioxide removal, which seeks to remove carbon from the atmosphere in order to lessen the greenhouse effect and thus slow warming, and 2) solar radiation management, or solar geoengineering, which attempts to increase reflection of solar radiation away from the earth in order to slow warming. Various types of solar geoengineering approaches include releasing reflective particles into the atmosphere (known as strategic aerosol injection) or spraying sea water into the lower atmosphere to generate brighter, more reflective clouds (known as marine cloud brightening).

It is important not to confuse carbon dioxide removal and solar geoengineering, two very different approaches, under the umbrella term "geoengineering." Carbon dioxide removal as a climate solution has been largely embraced, as the risk of unintended consequences is considered minimal. Solar geoengineering, on the other hand, presents a variety of complicating issues.

For example, despite research on the matter, a consensus does not yet exist around the ultimate overall climate impact of techniques like strategic aerosol injection. Some alarming models have predicted that certain schemes would cause droughts for a significant portion of the earth's population. Additionally, some predict the injection of aerosols into the atmosphere to cause increased depletion of the ozone layer. A long list of potential environmental complications like these exists in addition to complications that have not even been considered.

Artificially lowering global temperatures via solar geoengineering also presents the unique risk of "termination shock," meaning that if deployment of such geoengineering technology were suddenly discontinued, the resulting abrupt warming could become even more catastrophic than if warming had simply continued on its previous trajectory. Unpredictable events such as terrorist attacks, natural disasters, or political action all create risk for the sudden discontinuation of solar geoengineering and thus risk of termination shock.

Beyond climate concerns, solar geoengineering technologies also present a variety of new political and ethical questions. Although any ideal global geoengineering scenario would involve substantial international cooperation, some solar geoengineering techniques could be effectively deployed by a single country or a small group of countries acting in isolation. Even one extremely rich individual could conceivably deploy their own solar geoengineering project if allowed to do so by their respective government; in fact, a technique like strategic aerosol injection is relatively inexpensive despite its potential for worldwide environmental impact. Due to such great uncertainty and potential danger of the global impact of these technologies, unilateral geoengineering deployment is considered a very dangerous possibility.

Even if some sort of global consensus emerges regarding solar geoengineering deployment, the question of who controls the global "thermostat" remains. Who would ultimately have the authority to decide what kind and how much geoengineering should take place? How will decisions weighing global benefit against local or regional risk be made? How can it be ensured that geoengineering decisions aren't made to cause regional gains or losses? A world that features solar geoengineering use will need to answer these questions.

There is also the question of moral hazard—would the growing perception of geoengineering as a solution to climate change harm mitigation efforts around the world? The existence of moral hazard has been demonstrated empirically in many areas. For instance, it has been documented that increased healthcare insurance coverage results in increased demand for healthcare. The international community must consider the danger that geoengineering as global warming "insurance" could unintentionally generate additional planet-warming behavior, which is also amplified by the risk of termination shock.

Some also express concern over potential military applications of geoengineering techniques. In the past, militaries around the world have shown interest in controlling the weather, and it may seem logical to fear the weaponization of technologies designed for such purposes. However, given the uncertain nature of the effects of such technologies in addition to the international ban on military use of weather modification techniques, this particular risk may be less of a priority.

Given the potential threat that geoengineering could pose for the planet, it is important that the global community take steps to establish order in this space. While complete transparency among governments of the world would be ideal in theory, it is the unfortunate reality that some actors may pursue these activities unilaterally and in secret. The dangerous unknowns of such behavior require the capability to detect geoengineering activity wherever necessary. Early detection and localization of unannounced and unilaterally deployed geoengineering activities, either by private actors or states, requires adequate tools for rapid detection and response to maintain global security. The United States must develop its own realistic approach to preparing for emergency geoengineering scenarios. Given the danger that foreign geoengineering could present, the U.S. should establish proper security and deterrence mechanisms that can be carried out quickly and efficiently in case of potentially harmful geoengineering activity abroad.

Beyond surveillance, there is a dire need for a governance regime for global geoengineering activity. The inherently international nature of climate change and discussions of climate manipulation demand an international approach to governance. As worsening climate conditions are likely to generate continued worldwide interest in geoengineering deployment, the world cannot afford to wait until an emergency arrives if it hopes to navigate increasingly complicated climate and geoengineering scenarios. States should collaborate to develop and refine international norms and institutions to adequately prepare the world for the inevitable stresses of continued climate change and the resulting reaction from states and other actors.

III. Understanding geoengineering governance

The importance of an effective governance regime for global geoengineering is clear, but what it will look like is undetermined. To adequately answer this question, it's important to examine all facets of the geoengineering conversation.

Geoengineering governance is already the subject of academic research and debate. Often referenced in scholarly approaches to this issue are the Oxford Principles, a set of general guidelines created by a group of academics which was commissioned by the U.K. House of Commons Select Committee on Science and Technology. Although other similar efforts exist, the Oxford Principles have become the most influential. The five principles include 1) the regulation of geoengineering as a public good, 2) public participation in geoengineering decision-making, 3) disclosure of geoengineering research and publication of results, 4) independent assessment of impacts, and 5) governance before deployment. While these principles are useful in providing a theoretical lens for framing the geoengineering governance debate, they do not offer much in terms of realistic enforcement, a necessary component if norms like the Oxford Principles can ever be upheld.

A preliminary discussion for any governance regime concerns the regime's goal of governance: what outcome does the regime seek to achieve? For instance, a geoengineering regime might seek to facilitate or promote further research into geoengineering. On the other hand, the regime could be primarily concerned with preventing geoengineering from occurring altogether if it considers the possibilities too dangerous. Establishing a clear goal of governance will be essential to any regime-building process for geoengineering and will shape all elements of governance.

Once the goal of governance has been determined, one of the most important considerations of the regime will be the deterrence of geoengineering activity without international approval. Until the risks of solar geoengineering are better understood, an individual country, a small group of countries, or even an individual acting alone could cause serious global harm by engaging in solar geoengineering. While some argue that states are unlikely to go this route given the strong reaction that it would engender from the international community, the risk of unilateral deployment must still be taken seriously and addressed given that continually worsening climate change could cause states or other actors to act desperately.

An effective geoengineering governance regime must also adequately account for the behavior of non-state actors, as even a wealthy individual could theoretically perform solar geoengineering on their own. International law applies to individuals only indirectly, as states are responsible for implementing legislation within their own jurisdiction. Even more complicated are areas beyond national jurisdiction; governing geoengineering on the high seas or in the stratosphere would require additional attention. Successful governance of geoengineering will require substantial effort to incentivize and support states in preventing solar geoengineering by non-state actors while also determining who has jurisdiction over ambiguous areas.

A geoengineering governance regime needs to address geoengineering research as well as deployment. Many scholars have already called for "governance before research," although how to achieve such a result remains unclear. A moratorium on solar geoengineering field research, suggested by some, would be nearly impossible to impose. Funding of geoengineering research is also an important aspect of the conversation. International lending institutions such as the World Bank can serve as important governance tools via their ability to finance geoengineering projects. If geoengineering projects are eventually scaled up, private actors, too, will play a role in decision-making around geoengineering as they are called upon more greatly to provide requisite materials for geoengineering.

As previously emphasized, monitoring and intelligence will also be key to any geoengineering governance regime. Although an ideal governance regime would include representation of all countries of the world, it should be expected that some states will not cooperate, whether it be by joining a regime but ignoring any resulting mandates or by ignoring the regime altogether. For this reason, a reliable monitoring system that allows states to track geoengineering activity will be an important enforcement element of a successful regime. The Comprehensive Nuclear-Test-Ban Treaty provides a relevant example of an agreement featuring "wide-area environmental detection methods to verify state compliance." This will not be an easy task, as successful monitoring of certain types of geoengineering is extremely difficult, but the effort remains essential.

A potential geoengineering governance regime could take many forms in both the near and long terms. For example, one near-term approach might seek to use existing international institutions and agreements (listed in Table 1 below) that have jurisdiction over elements of geoengineering.

Table 1

Treaty or Convention	Relevance for Geoengineering
UN Framework Convention on Climate Change (UNFCCC)	Seeks to prevent dangerous interference in the global climate system
Environmental Modification Convention (ENMOD)	Prohibits environmental modification techniques for military purposes
UN Convention on the Law of the Sea (UNCLOS)	Establishes a duty to protect and preserve the marine environment
London Convention	Restricts ocean fertilization activities
Convention on Biological Diversity (CBD)	Restricts ocean fertilization activities

Some advocate for leveraging these agreements to govern geoengineering in the immediate future. However, others doubt that they will be sufficient as none contains norms that clearly relate to geoengineering activity. One prominent alternative short-term suggestion to address this gap in current international law involves calling upon scientists themselves to govern solar geoengineering research via voluntary codes of conduct. Some experts have recommended a code of conduct requiring researchers to run thorough environmental impact assessments alongside geoengineering research to prevent environmental harm as well as to establish a standard of transparency, perhaps via a voluntary registry of research projects in which geoengineering researchers provide public updates on their work. This, however, is unlikely to be a long-term solution as researchers in autocratic countries may pay little attention to such voluntary governance efforts. Yet given the improbability of a successfully implemented moratorium on geoengineering research activity, a code of conduct may still prove useful together with existing international law as part of a short-term approach to governance.

When formulating a long-term approach to geoengineering governance, it is useful to revisit other ambitious efforts in international governance that can provide insight on aspects of governance structure. For instance, the 1968 Non-Proliferation Treaty (NPT) is highly relevant given the similar global nature of the respective threats of nuclear proliferation and solar geoengineering, especially if the goal of governance is largely preventative. Analyzing the NPT's treatment of non-participants India, Israel, Pakistan, and North Korea could also be a useful exercise, as a similar challenge may exist for a geoengineering governance regime. Such non-cooperators have been a major problem for the international nuclear governance regime, one a geoengineering regime should do its best to avoid if possible.

Additionally, negotiations in the early 1980s under the United Nations Environment Programme regarding ozone-depleting substances led to the 1987 Montreal Protocol, widely considered a successful environmental agreement that began with 24 signatories and was eventually ratified by 197 countries. Its use of scientific assessment panels, clearly defined targets and schedules, a dedicated financial mechanism, and a system to monitor compliance are all features that will be important for a successful geoengineering governance regime. Additionally, trade restrictions utilized to deal with non-parties to the Protocol can serve as a model for a geoengineering governance regime should any states decide not to cooperate.

The 1966 Outer Space Treaty and the 1959 Antarctic Treaty both provide examples of international scientific cooperation and efforts to prevent militarization of unexplored territory. These agreements differ from arms control treaties in that a certain type of activity is being designated as taboo, which could resemble an eventual approach to geoengineering governance. Additionally, the flexible approaches to governance found in the cases of these agreements due to a high degree of scientific uncertainty around the issues at hand (as is the case in geoengineering, currently) can provide useful insight for promoting commitment to cooperation as collective understanding continues to evolve.

Borrowing the most useful and relevant elements of these governance regimes while paying special attention to where they fell short can help build a foundation for an eventual geoengineering governance regime. Such a framework should be flexible and science-based, should have an extensive technical and financial toolset to adequately manage the various aspects of geoengineering, and should be capable of dealing with any non-participants or violators with appropriate force.

IV. Recommendations for the Biden administration

Just as the international community needs to prepare for a world where geoengineering is more seriously considered as an emergency response to global warming, the U.S. has a responsibility to its own citizens to do what it can to prepare unilaterally for global geoengineering challenges. We propose three key steps that the Biden administration can take to protect against unauthorized geoengineering activities by other nations or non-state actors.

Develop capability for monitoring geoengineering activity

First, the United States should focus much of its effort on developing its own capability to effectively monitor geoengineering activity at any given location around the world. While the need for surveillance systems specifically designed to detect solar geoengineering has not been widely discussed, there are currently developing efforts to test a space-based surveillance approach for tracking methane emissions. This could provide important insight for geoengineering tracking given the similarities between how methane emissions and how the substances involved in certain methods of geoengineering will be detected.

Tracking solar geoengineering will also require a way to monitor the amount and size of artificial particulates in the stratosphere and the resulting climate effect. While climate change itself can be sufficiently monitored by existing orbiting satellites, monitoring solar geoengineering activity may need near-real time assessment and response to mitigate potential threats to national security. A constellation of satellites with persistent coverage could quickly detect and localize areas of interest that may be affected by geoengineering activity. Development of new satellite networks with new sensing capabilities will be essential to securing effective geoengineering monitoring and detection.

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Local sampling will also be necessary to detect the chemical composition of substances introduced into natural environments and quickly assess expected changes in climate dynamics. Climate researchers have constructed models that represent the results of techniques such as sulfate aerosol geoengineering and technologies for countering the effects of geoengineering, but these researchers need considerable additional data to calibrate and improve those models.

Eventually, a multi-layered surveillance system with early detection capabilities will be required, one which will need significant investment to advance the necessary technologies. Important technologies include high efficiency batteries and the exploration of alternative power sources as well as applying an innovative systems approach to energy distribution and recharging techniques. Also, the development of sensors and instruments that can operate in challenging and extreme environments such as in the Arctic, in the stratosphere, in the deep sea or during extreme weather events. Other technologies involved will include imaging spectrometers and lidar systems which have been proposed as methods not only to collect field test data but also to be used to detect various other possible signs of geoengineering activity. Additionally, investment in sensing technologies is needed as well as investment in advancing AI algorithms and computational systems which will be essential to enable near real-time computations and organize automated responses.

These technical advancements will better allow the United States to detect different types of geoengineering around the world early enough to allow for an appropriate and timely response.

Develop methods to deter and respond to unilateral geoengineering without international approval

Beyond surveillance and before the creation of an effective international governance regime with the capability to respond, the United States must prepare its policy response to scenarios in which other actors deploy geoengineering technologies without international approval.

To prepare an adequate response, the government needs increased scientific research into the effects of various solar geoengineering practices. There is still great uncertainty around how the deployment of various solar geoengineering techniques around the world would impact the global climate and affect the United States' security situation, so developing an appropriate response to the use of such technologies by foreign actors requires deeper familiarity with the risks associated with their use. For instance, if continued research and climate modeling strongly suggest that a certain type of solar geoengineering elsewhere in the world presents a serious threat to U.S. security or the security of its allies, the United States can tailor its policy response to meet the severity of the threat.

Such a policy will have to include answers to questions like what an example response might look like. The United States will need to develop a comprehensive plan of action based on its developing understanding of solar geoengineering technologies in the case that potentially dangerous activity should occur. What sort of immediate responses should be triggered? To what extent does it depend on who exactly is conducting solar geoengineering, or which particular technique is being used?

The tools deployed in responding to a geoengineering crisis will likely reflect the perceived threat of such geoengineering activity. If a foreign state is engaging in activity that has been determined to pose a genuine security threat to the United States or its allies, economic sanctions could provide an appropriately serious response without resorting to the use of military force. Research has shown that sanctions are most effective when implemented multilaterally via international institutions as well when major damage is inflicted on the target economy, two realities that also further emphasize the importance of international cooperation on geoengineering governance.

However, it is possible that the anticipated effect of foreign geoengineering activity might require more immediate intervention than counting on sanctions to eventually force the offending party to change its behavior. Research on "counter-geoengineering" practices has begun to explore possible efforts to actively counter the effects of geoengineering being conducted by others. This could amount to the use of a warming agent to balance the cooling effect produced by geoengineering or by physically disrupting the technology itself. While the back-and-forth development of geoengineering and counter-geoengineering technology would not reflect well on the status of global climate cooperation, further investment in counter-geoengineering could act as a geoengineering deterrent in itself.

Leverage existing international institutions and establish a voluntary code of conduct to promote global governance of geoengineering

Along with the development of robust surveillance systems and preparation of a policy response to foreign geoengineering activity, it is critical that the United States help drive and facilitate a global movement toward geoengineering governance. Certainly the U.S. should be prepared to monitor and respond to potentially harmful geoengineering activity. Yet given the inherent danger, uncertainty, and difficulty in doing so, an ideal outcome would involve no rogue geoengineering activity at all. Generating successful short- and long-term international governance for geoengineering, however difficult, is the safest way to achieve such an outcome.

What can the United States do to best promote geoengineering governance in the immediate future? First, use existing international institutions such as the UNFCCC—Article 2 of which states that its objective is to prevent "dangerous anthropogenic intervention in the climate system"—to legitimize conversations around geoengineering governance. Second, embrace and promote a universal code of conduct for research in the geoengineering space. Quickly establishing an official forum such as the UNFCCC for discussions related to geoengineering will be important in generating momentum towards a more comprehensive governance mechanism. Simultaneously, ensuring American scientists join other researchers around the world in adhering to a geoengineering code of conduct may help promote responsible and transparent research activity in this space in the near future, even if these efforts do not provide a long-term solution. Such an effort may also contribute to the development of relevant norms and processes that can provide the foundation for continued governance.

In the long term, it is in the best interest of the United States to promote the creation of a geoengineering-focused treaty under the United Nations or another international body. Again, the use of the United Nations provides an inherent sense of legitimacy to any governance effort, while a multilateral decision-making process allows for greater likelihood that wide participation may occur. Important elements of such a regime would include a legal mandate for deployment, a technical agency, and a governing body to set policy guidelines, among other elements. The agreement must require that member states enforce the decision of the body within their own jurisdictions while also determining jurisdiction over areas outside of national boundaries.

V. Conclusion

Although much is still unknown about geoengineering, the United States cannot afford to wait to act. By investing in robust surveillance systems, preparing internally for deployment of geoengineering technologies by foreign actors, and leading the way in the development of a global governance regime, the U.S. can greatly minimize the risk presented by increased interest in a human-controlled global climate.

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