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Abstract

The latest reports from the Intergovernmental Panel on Climate Change (IPCC) include an assessment of geoengineering—methods for removing carbon dioxide from the atmosphere, or cooling the Earth by reflecting more of the sun's radiation back into space. The IPCC assessment signals the arrival of geoengineering into the mainstream of climate science, and may normalize climate engineering as a policy response to global warming. Already, conservative forces in the United States are promoting it as a substitute for emissions reductions. Climate scientists are sharply divided over geoengineering, in much the same way that Manhattan Project scientists were divided over nuclear weapons after World War II. Testing a geoengineering scheme, such as sulfate aerosol spraying, is inherently difficult. Deployment would make political decision makers highly dependent on a technocratic elite. In a geoengineered world, experts would control the conditions of daily life, and it is unlikely that such a regime would be a just one. A disproportionate number of scientists currently working on geoengineering have either worked at, or collaborated with, the Lawrence Livermore National Laboratory. The history of US nuclear weapons laboratories during the Cold War reveals a belief in humankind's right to exercise total mastery over nature. With geoengineering, this kind of thinking is staging a powerful comeback in the face of climate crisis.

Keywords

climate change, David Keith, Edward Teller, geoengineering, IPCC, Lawrence Livermore National Laboratory, solar radiation, Winston Churchill

The decision by the Intergovernmental Panel on Climate Change (IPCC) to include a detailed assessment of geoengineering in its Fifth Assessment Report brings climate engineering from the fringes of the policy debate into the mainstream. When, in 2006, Paul Crutzen published his controversial essay calling for a program of sustained research into sulfate aerosol spraying as a method of blocking some of the sun's radiation to help cool the planet, he broke a long-standing taboo among climate scientists on talk of geoengineering (Crutzen, 2006). With the floodgates opened, research and publication accelerated rapidly. However, the climate science community remains sharply divided, in a way reminiscent of the divide over atomic weapons after World War II.

A taboo on talking about geoengineering remains among politicians and policy

makers, who fear accusations of bad faith if they promote Plan B when it is they who are in a position to implement the superior Plan A, cutting greenhouse gas emissions. With anxiety among climate scientists rising, and the global community still unable to agree to a program of emission reductions, the gap between what must be done and what is being done grows wider each year, and it seems only a matter of time before the political floodgates are opened to geoengineering.

The recent publication of reports by Working Groups II and III of the IPCC, which provide a detailed assessment of geoengineering, may be the event that triggers the opening. In a sense it does not matter whether the IPCC takes a skeptical view or a more positive stance. The fact that the IPCC now includes geoengineering among the potential policy responses to global warming gives permission to those who have been supporting geoengineering in private to do so in public.

Moreover, the IPCC's formal acknowledgement of climate engineering as a possible response emboldens those in the climate science community who are promoting Plan B, and none more so than Harvard physicist David Keith, the most influential advocate of geoengineering research (his influence and commercial engagement are detailed in Hamilton, 2013). Eli Kintisch, author of *Hack the Planet* (2010), describes Keith and Stanford scientist Ken Caldeira as the "geoclique," because of their long-running advocacy and the central role they have played in almost all reports on the subject. In Keith's recent, short book, *A Case for Climate Engineering*, he puts to the general public for the first time a rationale for injecting sulfuric acid into the upper atmosphere to create a layer of tiny particles between the Earth and the Sun (Keith, 2013). By mimicking the effect of a large volcanic eruption, such a solar shield could be adjusted as desired to reduce the amount of solar radiation reaching the Earth's surface and so cool the planet.

Until 2013, Keith had advocated only a research program, but in his new book he offers "a specific scenario for deployment" for the solar shield: beginning with theoretical and laboratory work, followed by experiments in the atmosphere, moving to minimal deployment and then, absent unpleasant surprises, commencing gradual full deployment, perhaps as early as 2025 (Keith, 2013: 80–86). Keith's proposal that we should not merely conduct a research program but actually deploy the solar shield raises the stakes considerably. He proposes that we start slowly and increase the injections until there are enough sulfate particles in the stratosphere to slow by half the rate of human-induced warming. Going only halfway, he argues, will sharply reduce the risk of altering global rainfall patterns.

In some of his writings, Keith expresses confidence in humanity's ability to regulate the Earth's climate. Other atmospheric scientists have more doubts. Alan Robock at Rutgers University is the most influential climate scientist publishing papers that take a skeptical view. In an article in the *Bulletin*, Robock (2008) listed 20 reasons why geoengineering may be a bad idea.

One of Robock's arguments was that the climate effects of solar radiation management, once deployed, would be difficult to isolate from the effects of natural variability and the impacts of anthropogenic warming. This is a

decisive argument against Keith's proposal for a slow ramp-up of sulfate injections, and leads to a broader questioning of the role of scientists like David Keith in a climate-challenged world. It would take at least a decade of full deployment before enough data were available to judge confidently whether the solar filter was working as planned (Robock et al., 2010).[1]

If Robock is right, his assessment drives a dagger into the heart of Keith's ramp-up scheme, which aims to slow warming by "a fraction" of a degree Celsius (Keith, 2013: 85). If it would take a decade to generate the data needed to assess full deployment, it would take much longer with Keith's proposal to start slowly and go halfway. With no decipherable information coming in, scientists would be flying blind for a very long time. The scheme therefore violates the first principle of engineering systems. That is, after initially setting the control variables, the engineer must obtain feedback from the system before adjusting the settings to make it work optimally.

This problem is quite well known. Given its importance, one would expect Keith to include a robust rebuttal of Robock's argument in his book, but he does not. When he does mention the argument, he claims it is "doubly wrong" (Keith, 2013: 63). How? First, he says, we can learn a lot from field tests that have a large signal in a local environment with little noise. It is true that tests can tell us important things about atmospheric chemistry, but they can tell us next to nothing about the effects of solar geoengineering on the *global* climate.

Secondly, Keith writes, "even if it were tested at 'full scale' we will still not resolve all our uncertainties." In this mystifying statement he seems to be saying that the objection is even stronger than Robock and other critics claim. That's all he says. Keith's response to the killer objection to solar geoengineering is to not engage with it.[2]

A world controlled by scientists

Even if Robock's objection were not fatal to sulfate aerosol spraying, the data problem prompts some deeper concerns. Any deployment program would depend heavily on a complex array of atmospheric measurements. Models would aggregate and assess the streams of incoming data on land, sea, and air temperatures; on precipitation around the world; on unusual weather patterns; and on atmospheric chemistry, including ozone depletion and the rates at which sulfur particles fall out of the stratosphere. Models would also be used to make projections about the combined effects of sulfate injection and elevated carbon dioxide concentrations. Decision makers in government would therefore be highly dependent on a technocratic elite at what would effectively be a global climate regulatory agency.

It's worth noting the apparent paradox of conservative think tanks (such as the American Enterprise Institute, the Cato Institute, and even the extremist Heartland Institute),[3] which for years have rejected the validity of climate science, now expressing support for geoengineering. They are endorsing a solution to a problem they claimed does not exist (Hamilton, 2013). For them, geoengineering promises to turn a drastic failure of the free enterprise system into a triumph of human ingenuity. Instead of climate change being a vindication of environmentalists' warnings,

geoengineering exposes the greens' lack of faith in humanity. Rather than shrinking from technological hubris, conservatives are calling for greater mastery over nature. However, conservatives who favor solar geoengineering seem not yet to understand that, in seeking to avoid government regulation of fossil fuel use, they are endorsing government regulation of the climate, and doing so through a scientific bureaucracy that would be far more powerful than the IPCC. To be sure, such a bureaucracy would not regulate individual behavior, but it would regulate the conditions in which individuals behave.

Beyond the ideological contortions of conservatives, what can be said about decision making in a geoengineered world? Geoengineering advocates seem to be at home in the world of technocratic control. Keith implies that a separation can be maintained between the pure domain of science and technology, and the arena of politics that threaten to sully it—creating what he calls "a world without politics," (2013: 87) in which scientists could be trusted to exercise power, justly and objectively, over the world's climate.

When future political leaders must make decisions on climate control, which scientists will they turn to? History suggests they will choose the ones they most trust. Trust has a contingent relationship with expertise. As a rule, political orientation comes before expertise. It was not only Edward Teller's reputation as "the father of the hydrogen bomb" that turned him into one of the foremost architects of the Cold War, but also his strident anti-communism. With unmatched access to the Republican White House, Teller was even invited into the Pentagon to help choose the Russian cities and military facilities to be obliterated in a first strike (Broad, 1992: 20).

In a world of climate control, the practice of politics would change along with the weather. We have seen this before with world-shifting technologies. Steven Shapin recently wrote about Winston Churchill's wartime ruminations over Britain's commitment to building an atom bomb:

> . . . the distinction between the domains of science and politics is put under pressure when there is a prospect that the nature of politics, diplomacy, and the use of military force will be transformed by the existence of new science and new technologies. (Shapin, 2013: 36)

Churchill, writes Shapin, "suspected that [scientists] had a pernicious wish to parlay technical expertise into political influence." He took the view that scientists should have no more influence on government policy than dentists. But politicians often have no choice, so Churchill surrounded himself with a small group of men who had won his trust. His job was to "adjudicate between the boffins" (Brendon, 2013).

However, as the historian Graham Farmelo has shown, Churchill came to rely on one adviser in particular, the Oxford physicist Frederick Lindemann. Lindemann was not a top-ranked scientist, but he was of Churchill's social class and political convictions and, most usefully, he was skilled in the art of flattery (Farmelo, 2013). (When criticized for his unhealthy closeness to Lindemann, Churchill responded: "Love me, love my dog.")

Even so, Churchill always retained a healthy skepticism of the boffins. In a 1937 newspaper article titled "Life in

a World Controlled by the Scientists," he wrote:

> . . . there are secrets too mysterious for man in his present state to know; secrets which once penetrated may be fatal to human happiness and glory. But the busy hands of the scientists are already fumbling with the keys of all the chambers hitherto forbidden to mankind. (Churchill, 1937)[4]

The words have an eerie contemporary relevance. While perhaps not all would concur with Churchill's conviction that there are rooms best left locked, most would agree with him that our moral development, self-control, and political institutions often lag well behind our formidable scientific insights and technological prowess. "It would be much better," he declared, "to call a halt in material progress and discovery rather than to be mastered by our own apparatus and the forces which it directs" (1937).

A geoengineered world would be one in which the conditions of daily life would be set by experts far away and human nobility, as Churchill might have put it, would no longer be possible, not so much because humanity would inhabit an artificial Earth but because humanity made it *necessary* to inhabit an artificial Earth.

Given that humans are proposing to engineer the climate because of a cascade of institutional failings and self-interested behaviors, any suggestion that deployment of a solar shield would be done in a way that fulfilled the principles of justice and compassion would lack credibility, to say the least. Humanity finds itself in a situation where geoengineering is being proposed because of our penchant for deceiving ourselves and inflating our virtues.

If a just global warming solution cannot be found, who can believe in a just geoengineering regime? Studies have shown that a solar filter would offset the impacts of global warming more effectively in some parts of the world than others. In some areas it may exacerbate droughts. The temptation of those who control the heat shield to manipulate it in a way that suits their own interests would be ever-present and almost irresistible. No wonder nations of the South are leading early moves, notably through the Convention on Biological Diversity, to impose restrictions on geoengineering.

Scientific naïvetè

Whatever the motives and professionalism of geoengineering researchers, the idea is already attracting a range of other actors with a diversity of purposes and standpoints, not all of them admirable. It would be naïve of researchers to imagine they can isolate themselves in a cocoon of scientific neutrality. Nor can they absolve themselves of responsibility for how their schemes might be used or misused in the future. These technologies are, after all, designed to regulate the conditions of life. Once political, corporate, and military players become involved, geoengineering experts will lose control of how the technology is used.

Already, military organizations are taking an interest. The Pentagon's Defense Advanced Research Projects Agency convened a meeting in 2009 to consider geoengineering. The semi-secret, military-linked JASON group of top scientists who advise the US government is also reported to be studying geoengineering (Kintisch, 2009). The

Central Intelligence Agency is currently funding a report (Aldhous, 2013).

In a messy world of climate control—in which political, strategic, and commercial interests collide—the role of experts will be complicated. Essentially, though, they will have a choice: to go along with the authorities' program or get out. Edward Teller and Robert Oppenheimer, who played vital roles in the Manhattan Project, faced a similar choice. Oppenheimer, often called the father of the atom bomb, spent many of the post-Hiroshima years trying to limit the spread of nuclear weapons. While Oppenheimer worked to restrain the monster he had helped to create, and so earned the ire of the authorities, Teller worked assiduously to place himself at the very center of the nuclear arms race and attained power unprecedented for a scientist. He could do so because he was the most aggressive advocate of nuclear bombs, including their use for civil engineering projects.[5]

If controlling the world's weather becomes central to the exercise of global strategic and military power—as nuclear weapons did after World War II—which path will today's geoengineering researchers take, Oppenheimer's or Teller's?

Geoengineering at Livermore

A disproportionate number of scientists today working on geoengineering have either worked at, or collaborated with, the Lawrence Livermore National Laboratory (Hamilton, 2013).[6] This suggests that the history of Livermore may provide some insights into the deeper ideas behind climate engineering and the way some geoengineers understand the human relationship with the Earth. The best source on Livermore's culture is Hugh Gusterson's (1996) study *Nuclear Rites: A Weapons Laboratory at the End of the Cold War*.

Established in 1952, the laboratory was at the center of the US program to develop and test nuclear warheads. Cofounded by Ernest Lawrence and Edward Teller, it soon became the most vigorous advocate of the hydrogen bomb. Teller himself, fiercely anti-Soviet, became a central player in the Cold War. Under his leadership, the lab acquired a "near-mythological status as the dark heart of weapons research" (Goodell, 2006).

Weapons researchers came to believe that their technical expertise gave them a privileged role in advising government on nuclear policy. Among weapons scientists, the conviction grew that understanding and exercising control of the technologies was sufficient to render them safe, as if mastery of the technical sphere carried over into the political sphere. Confidence in the technology spilled over into the structures that determined how and when nuclear weaponry might be used, reflecting the modern predilection to elevate technical understanding over other kinds of understanding, so that those who could speak with authority in the former acquired the right to speak in the latter.

In the emerging geoengineering field, scientists have assumed a privileged place in advising not merely on technical questions but on governance arrangements, ethical concerns, and international negotiations, despite their lack of expertise. The two reports of the Royal Society (the United Kingdom's national academy of science), along with a number of other influential reports written by groups dominated by

scientists, are evidence of that. Some scientists take the view that if one is clever enough to understand atmospheric physics then one is also clever enough to grasp the nuances of politics, social change, and ethics—which don't appear too hard or to require sustained study.

Livermore scientists were not opposed to nuclear arms control treaties, but they were hostile toward test bans. There is a similarly strong resistance among many geoengineers to any regulation of research and testing, especially by the United Nations. At Livermore, antipathy to test bans was not merely pragmatic. Gusterson divined deeper cultural meaning in testing. The "display of the secret knowledge's power" imparted a keen sense of community among participants. Weapons tests were "powerful rituals celebrating human command over the secrets of life and death" (Gusterson, 1996: 155, 234). They were proof that human mastery of dangerous powers could be attained. One might likewise expect that tests of geoengineering technologies, if successful, would persuade those carrying them out that technologies of planetary control can be mastered. The Promethean view allows one to rise above the serious objection, posed by Robock and his colleagues (2010), that the only way to know whether sulfate aerosol spraying would work would be full deployment.

Those who worked at Livermore during the Cold War found a culture in which brilliant and often quirky scientists dreamed up and tested big technological schemes to protect Americans' freedom and advance US strategic interests around the world. In the 1980s, the Reagan administration poured more than a billion dollars into Livermore to fund the Star Wars program, which promised to develop a fleet of nuclear-powered satellites that could use enormously powerful lasers to vaporize Russian missiles. At the heart of Star Wars were Edward Teller and his protégé Lowell Wood (Goodell, 2010).

With the collapse of the Soviet Union and the end of the arms race, Livermore lost much of its *raison d'être*. Its leaders argued that weapons scientists were still needed to respond to threats from emergent nuclear nations and terrorist groups, but they also began to look for new opportunities to keep the laboratory relevant. As it happened, nuclear weapons research spilled over into atmospheric science, since one of its tasks was to evaluate the effects of a nuclear exchange on the climate. That task required the development of sophisticated models to track the distribution of smoke, dust, and radiation. This capacity was expanded in the 1990s to study the effect on global climate of rising greenhouse gases in the atmosphere.

In 1997, the laboratory published a paper by Teller, Wood, and Roderick Hyde, a senior scientist at Livermore, titled "Global Warming and Ice Ages: Prospects for Physics-based Modulation of Global Change." It was one of the first papers to argue forcefully in favor of sulfate aerosol spraying as a response to global warming, praising technological interventions instead of "international measures focused on prohibitions" (Teller et al., 1997: 3). Expressing cynicism toward democratic decision making, the authors argued that a new technology of solar radiation management would be able to cut through international disagreements and win over public support. Teller wrote soon after: "Let us play to our uniquely American

strengths in innovation and technology to offset any global warming by the least costly means possible" (Teller, 1997).

Five years later, Teller, Wood, and Hyde returned to the theme with a paper arguing even more strongly that the world should regulate solar radiation instead of attempting to reduce greenhouse gas emissions (Teller et al., 2002). Still casting doubt on the science of climate change, they set out ways to manage solar radiation actively, which they insisted was the most practical approach to global warming. Claiming that the environmental risks of a solar shield would be "negligible," the question, they wrote, was no longer whether we should engage in solar geoengineering but only how best to do it. Not only would geoengineering be technically easier, politically preferable, and environmentally benign, the Livermore trio argued, but sulfate aerosol spraying would have large economic benefits—in the form of reduced skin cancer rates and improved agricultural productivity due to higher carbon dioxide concentrations—that would render it worth undertaking even in the *absence* of any problematic global warming.

Man over nature

As the story of Livermore suggests, the belief in humankind's right to exercise total mastery over nature defines a powerful strand of US technological thinking that became dominant in the post-war decades. It was challenged by the rise of the environmental movement in the 1970s and 1980s. Now it seems that the challenge caused only a temporary retreat and that Promethean thinking is staging a powerful comeback in the face of climate crisis, a thinking bluntly expressed by Lowell Wood in defense of geoengineering: "We've engineered every other environment we live in—why not the planet?" (Goodell, 2006).

It is apparent too in David Keith's worldview. After reminding us of the enormous, Earth-shaping power of geoengineering technologies,[7] Keith concludes that "there do not . . . appear to be physical limits that prevent a technologically advanced civilization from tailoring radiative forcing [sunlight] in an arbitrary manner" (2013: 103). The new twist, which many will find disturbing, is that he believes there is nothing inherently desirable about the stable and clement Holocene climate the Earth enjoys today. As long as climate engineering is performed slowly enough for humans and ecosystems to adapt, Keith sees no reason why we should not use our technological power to create a quite different climate on Earth. And since the climate system is inseparably linked to all other parts of the Earth system, that means he views with equanimity the creation of a new Earth by human means.

It is perhaps for this reason that David Keith and other "eco-pragmatists" seem mystified by the instinctual hostility many feel toward the idea of creating an artificial planet through climate engineering. In his book, Keith reminds us of his love of the wild, but his words suggest that he has no philosophical commitment to the Earth as we know it. He sees nothing special in the climate of the Holocene, the 10,000-year epoch that permitted civilization to flourish. For him, a natural Earth has no intrinsic claim over a human-made one.

Perhaps injudiciously, Keith expresses a sentiment felt by some other

geoengineering researchers—his *excitement* about the prospect of using solar geoengineering to transform the Earth. He speaks approvingly of humanity's "new powers to shape the planetary environment" and of his hope that we will use them to "build a thriving civilization." His final words express his "delight in our new tools" (2013: 173–174). For many, that the world's leading geoengineering advocate should find delight in the prospect of using technology to create a new Earth will come as a shock, and only increase their anxiety that the world could soon embark on the most dangerous experiment ever conceived.

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Notes

1. Robock et al. (2010) note that the cooling effect of large volcanic eruptions can be detected but that of small ones cannot: "... weather and climate variability preclude observation of the climate response without a large, decade-long forcing.... The signal of small injections would be indistinguishable from the noise of weather and climate variations."
2. When I put the objection to Keith in a public forum in October 2013, he responded by saying that it was he, not Alan Robock, who first identified the problem and that we would need not 10 years of data but 20.
3. While publishing and promoting papers advocating geoengineering as a substitute for mitigation, the Heartland Institute claims it does not have a position on geoengineering (Appell, 2013).
4. I am grateful to Graham Farmelo for supplying me with a copy of this hard-to-obtain document.
5. Teller's Project Plowshare, launched at the Lawrence Livermore National Laboratory, aimed to use nuclear explosions to move mountains, open up canals, and gouge out new ports.
6. They include Lowell Wood, Roderick Hyde, Ken Caldeira, Mike MacCracken, Greg Rau, Ron Lehman, Jane Long, Brad Allenby, Govindasamy Bala, and Haroon Kheshgi (Hamilton, 2013).
7. "These technologies give humanity unprecedented leverage over global climate and that leverage can be used for good or ill" (Keith, 2013: 111).

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Author biography

Clive Hamilton is an Australian author and professor of public ethics at the Centre for Applied Philosophy and Public Ethics, a joint center of Charles Sturt University and the University of Melbourne. From 1994 to 2008, he was the executive director of the Australia Institute, a progressive think tank he founded. In 2012, the Australian federal government appointed Hamilton to its Climate Change Authority. His books include *Scorcher: The Dirty Politics of Climate Change* (Black Inc. Agenda, 2007), *Requiem for a Species: Why We Resist the Truth about Climate Change* (Earthscan, 2010), and *Earthmasters: The Dawn of the Age of Climate Engineering* (Yale University Press, 2013). He is now writing a book on the Anthropocene.