Towards the anticipatory governance of geoengineering: Ethics, Politics, and Governance

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Geoengineering Our Climate? is a Working Paper and Opinion Article Series that explores the ethics, politics and governance of geoengineering – the intentional manipulation of the global climate to counteract climatic changes. Relying upon the efforts of over forty contributing authors from academia, policy, and civic environmentalism, our objective for this project is to create a comprehensive yet broadly accessible introduction to the complex societal dimensions associated with the emergence of geoengineering. Our Convening Partner organizations include high-profile institutes from across the global north and south: the Institute for Advanced Sustainability Studies (Germany); the Institute for Science, Innovation and Society, University of Oxford (UK); the Consortium on Science Policy and Outcomes at Arizona State University (US); the Council on Energy, Environment and Water (India), the Research Centre for Sustainable Development of the Chinese Academy of Social Sciences (China), and the Brazilian Research Group on International Relations and Climate Change (Brazil).

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We can never know about the days to come/
But we think about them anyway.
– "Anticipation", by Carly Simon

Introduction to Anticipatory Governance

Simon's lyrics contemplate a future that is imminent but still uncertain, that is capacious but might not hold what she desires. Above all they recognize that "anticipation" is fundamentally ambiguous because what we get may not quite be what we were hoping for. We don't want to rush headlong into a future dominated by either unchecked global warming or the risks of planetary-scale climate interventions rendered real. Yet our ignorance is vast, and our ability to predict is overwrought: "I'm no prophet and I don't know nature's ways." So we are left to anticipate.

Anticipation, however, is not purely passive. Before the future manifests, we can do much more than hum a tune.

This chapter aims to describe what we call "anticipatory governance," which refers most directly to building the capacity to manage emerging technologies while such management is still possible. We test this concept on geoengineering, a set of emerging technologies and techniques. Yet, a similar approach could be used for synthetic biology, biotechnologies, information and communication technologies or robotics. The category is not limited to contemporary technologies; the railroad in the 19th century, for example, or nuclear weapons in the 20th, might be two historical examples of emerging technologies, even if it is too late to anticipate them now.

The issue with emerging technologies is not that they are new, if by new we mean unprecedented. In the field of nanotechnology, chemists, materials scientists, and others have performed research at the nano-scale for decades, while biologists who have performed research under the label of synthetic biology may argue that it is indistinguishable from molecular biology or genetic engineering research. Geoengineering in this sense has a much longer pedigree through the vast changes made by humans to landscapes, coasts, ecosystems and watersheds, not to mention more recent, explicit efforts to modify the weather.[1]

But having precedent is not the same as being same-old-same-old. Likewise, raising issues of novelty does not necessarily mean raising novel issues – a technology does not have to raise an issue never before seen for it to be novel. Being novel in a particular context is sufficient for serious attention, for example, as even a familiar species in a new environment can become an invasive pest. It is precisely that emerging technologies both have antecedents and are new – that they have what we would call a *politics of novelty* – that makes them interesting and problematic.[2]

Using nanotechnology as an example, the politics of novelty revolve around funding.

[1] Fleming 2010
[2] See Guston, 2014; see also Rayner 2004 for his similar "novelty trap"

For example, the US National Nanotechnology Initiative (NNI) coalesced research efforts previously conducted in disparate disciplines and enacted favorable budgetary treatment. Nano's politics of novelty includes issues of intellectual property and regulation: If materials and their properties are so novel as to be protected by patents, can they at the same time be similar enough to pre-existing materials at the bulk scale to warrant no special regulatory attention? And issues of risk: If these properties are so novel, why assume that they are benign in the human body or external environment? For synthetic biology, the politics of novelty revolves around the questions of when, during millennia of animal husbandry and breeding plants, do the ambitions of researchers to reconceive of life in engineering terms demand a reconceiving of regulation, governance, and even ethics as well?

For geoengineering, the politics of novelty revolves around the ostensible transition from self-conscious but small-scale interventions in the earth system, e.g., weather modification of various sorts and environmental restoration and larger-scale but less self-conscious interventions such as industrial-scale agriculture, fossil fuel emissions and the like, to interventions that would be both large-scale and self-conscious. After we recognize what we have already done (without quite being aware of it) there is no Nature left out there – in Stewart Brand's language, "it's all gardening" but at a planetary scale.[3] As this volume so aptly describes, there are other political issues – e.g., the vexing flip-side to the collective action problem of climate change in which a single nation or lone private actor could, perhaps, "solve" the problem.

In addition to the politics of novelty, emerging technologies like geoengineering are characterized by the combination of high stakes and high uncertainty that characterizes what Funtowicz and Ravetz (1993) identify as "post-normal science".[4] For geoengineering a major challenge is the radical uncertainty associated with such a technological solution coupled with the high stakes involved (for those who may see themselves as potential losers or winners), and the growing sense of urgency among some scientists and activists. Post-normal science explicates the challenges for "building knowledge that:

1. appropriately accounts for the societal and technical dimensions of societal problems;
2. directly contributes to problem solving;
3. legitimately includes diverse types of knowledge; and
4. credibly connects to the local contexts that inform socio-technical problems".[5]

Those aspects invite a new set of operating conditions for geoengineering research, which includes "extended peer review" or public engagement in decisions otherwise left to scientists alone in normal science.[6] Such engagement may be relatively spontaneous, arising from the publics them-

[3] Brand 2010

[4] Guston 2014

[5] Bernstein et al. 2014, 2493

[6] Funtowicz and Ravetz 1993

selves, as with public skepticism and opposition to nuclear power in the 1960s to embryonic stem cells in the 2000s.

Alternatively, public engagement may be premeditated and even somewhat contrived by government or civil society groups, for example via consensus conferences aimed at eliciting public views through formal deliberative activities. Anticipatory governance builds upon such activities by envisioning two additional capacities: anticipatory knowledge that does not seek to make predictions or probabilistic forecasts; and integration of social scientific and humanist knowledge with practices with natural science and engineering research.[7]

This chapter next explicates a rationale for anticipatory governance and its three conditions: foresight, engagement, and integration. Next we test its use as an evaluative tool for discursive and governance processes by investigating five early reports on geoengineering – including geoengineering's own Asilomar meeting. Our analysis offers evidence that elements of anticipatory governance are in practice and that we may, in fact, be doing better than we have done recently with nanotechnology or with genomics; however, work remains to be done to clarify and specify the conditions for practicing anticipatory governance well enough to realize the ideals of deliberative democracy to reflect the values and capabilities of pluralistic societies. "Well enough" would not mean the "control" of emerging technologies, an impossible and even incoherent goal.[8] If we cannot do well enough, we may indeed look back and decide that we should "stay right here 'cause these are the good old days."

Why Anticipatory Governance?

Anticipatory governance is a vision for dealing with emerging technologies by building the capacity to manage them, while management remains possible. It stands upon two concepts: One, governance, is a broad-based societal capacity to make collective decisions. It is not synonymous with, but includes, government action (e.g., treaties or legislation) as well as non-governmental action (e.g., market pricing or protests) and activities that require public-private collaborations (e.g., standards) or that occur in both public and private contexts (e.g., funding and subsidies, insurance and indemnification). Guston points out that taking a governance perspective does not promote a neo-liberal agenda, but recognizes that the "complicated political economy of technoscience" cannot be squeezed into crude dichotomies like government versus market or promotion versus banning.[9]

Two, anticipation, expresses a particular kind of disposition toward the future governance. It is our perspective that all governance requires some explicit disposition toward the future, but anticipation stands apart from, say, prediction or precaution.

[7] Barben et al., 2008; Guston, 2008; Sarewitz, 2011; Guston, 2014

[8] Stirling 2014

[9] Guston 2014, 226-227

An anticipatory disposition is not about seeing into the future (prudence) or saying what the future is going to be (prediction) or estimating the chances of a certain outcome (probabilistic forecasting), all of which prescribe a "knowledge first" approach to action.[10] Rather, from Latin for "prior" and "capacity," anticipation is about doing something now, like building a capacity, in preparation for something that might occur in the future. Similar to precaution, it recognizes a radical uncertainty. But it differs from precaution because precaution implies some difficult-to-specify demarcation between a state of action and a state of inaction, and often acknowledges an easing of uncertainty based on more research or more data, which anticipation does not.[11] Precaution prescribes a waiting game that is potentially self-defeating, as new information may never resolve uncertainty, and waiting may forego benefits derived from innovation.

The Center for Nanotechnology in Society at Arizona State University (CNS-ASU) adopted anticipatory governance as a strategic vision due to shortcomings with predictive and precautionary approaches. This led CNS-ASU to design research programs that helped develop the capacities of foresight, engagement, and integration. While CNS-ASU has popularized anticipatory governance for nanotechnology and others have begun to discuss it for synthetic biology[12] and geoengineering[13], still others have discussed it more broadly. As anticipatory governance spreads through academic literature and into practice, it is worthwhile reflecting on its origins, its reasons for being, and in response to those like Global Economic Forum[14], its authentic tenets.

Karinen and Guston (2010) and Guston (2014) explain that while the origin of the term itself is largely obscure, scholars began using anticipatory governance in a coherent way about 2000, in public administration, environmental policy, and soon thereafter in nanotechnology. Yet one may trace the conceptual roots of anticipatory governance back to Alvin Toffler's best-selling *Future Shock* (1971), which introduces the cognate term of "anticipatory democracy." He articulates a marriage of New England-style participatory democracy to the somewhat novel (however, technocratic) means of strategic and long-range planning, budget forecasting, and the like. Toffler's rationale for anticipatory democracy is cognate as well; he intends it to be therapeutic for "future shock," a societal malady induced by rapid technological change, about which Tof-

[10] Sarewitz et al. 2011
[11] Dupuy 2007
[12] Gorman 2012
[13] Macnaghten and Szerszynski 2013

[14] Global Economic Forum (2012, 22) contrasts it with precaution: "More promising is the approach of 'anticipatory governance.' In this model, regulators accept the impossibility of anticipating the potential trajectory of innovations based only on past experience. They embrace the need for dynamic safeguards that can evolve with the system they are safeguarding. Anticipatory governance implies close, real-time monitoring in the direction in which innovations evolve, and involves defining safeguards flexible enough to be continually tightened or adapted in response to emerging risks and opportunities. The model of anticipatory governance is attracting attention in fields ranging from climate change to personalized medicine."

fler harbored some seemingly determinist views.

Toffler does not specifically contemplate integration of social science into natural science to slow or steer innovations responsible for future shock. Perhaps ironically, integration can trace its genealogy back to post-World War II policy, as the United States was refashioning its research enterprise from its war-time exigencies. Politicians and scientists battled over such issues as democratic accountability of civilian research, intellectual property, and (pertinent to this discussion) the role of the social sciences. Many elite natural scientists believed the social sciences were technically and perhaps ideologically suspect, and thus should be left out of publicly funded research for fear of tainting the whole endeavor. Detlev Bronk – who would go on to become president of the National Academy of Sciences, Johns Hopkins University and Rockefeller University – voiced support for the social sciences. While his sentiments were instrumentally oriented, Bronk nevertheless argued that "[c]ompetent social scientists should work hand-in-hand with natural scientists, so that problems may be solved as they arise, and so that many of them may not arise in the first instance".[15]

Bronk did not win the day, and the social sciences needed another generation – till Toffler's time – to receive but junior membership in the formal scientific establishment. At approximately the same time, Congress created the Office of Technology Assessment (OTA) in 1972. However, the OTA tilted in a distinctly technocratic direction and away from Toffler's participatory impulse.[16] The OTA also never quite managed to develop aspects of technology assessment that dealt with foresight, due largely to the purview of its congressional client. Its work essentially became policy analysis with a particular focus on science and technology.[17] Not until two decades later when the US Human Genome Initiative created its program on the ethical, legal and social implications (ELSI) of genomic research, did a research program acknowledge that funding societal research might be a wise complement to potentially transformative science. The separation between "real science" and ELSI was an explicit part of the deal, and there was little thought that insights emerging from ELSI would (or should) feed back into policy processes steering genome science.[18]

After the closure of OTA and the modest achievements of the genome ELSI program[19], Guston and Sarewitz (2002) called for a more decentralized, more constructive (e.g., Schot and Rip 1997), more participatory technology assessment that could support anticipatory governance. While Science and Technology Studies was late to the party[20], social science publications addressing nanotechnology have increased rapidly since 2006.[21] This in-

[15] Bront 1975, 413

[16] Bereano 1997; Sclove 1995

[17] Bimber 1996

[18] Cook-Deegan 1994

[19] McCain 2002

[20] Bennett and Sarewitz 2006

[21] Shapira et al. 2010

crease is fueled by mandates in many countries to include social and ethical research along with nano-scale science and engineering research. In some cases societal research on nanotechnology, as in CNS-ASU or scholars in the United Kingdom working on responsible innovation[22], built capacity to address geoengineering.

We cautiously suggest, then, that starting in the mid-1970s there has been some evolution of theory, practice, and policy toward an explicit commitment to anticipatory governance to address the uncertain futures of emerging technologies. The main evolutionary threads are: 1) a continual distancing from the naïve belief that the future of technologies-in-society is predictable and can be governed as such; 2) an increasing commitment to more formal mechanisms of public participation in both anticipation and governance of emerging technologies; and 3) an increasing role for social science through integration with natural science in seeking to come to grips with the socio-technical complexities of emerging technologies.

Anticipatory Governance in Action?

What looks to be an emergent, if informal and unorganized capacity for anticipatory governance appears to be coalescing around geoengineering. Scientists and science organizations, non-governmental organizations, and government bodies are applying their capacities to begin imagining what geoengineering might be like, planning what research might be necessary to achieve (or avoid) imagined futures, and what institutional designs and guidelines might be necessary to govern research and possible deployment. These early efforts include the vocal presence of social scientists and humanists and disparate activities aimed at understanding public attitudes about geoengineering and engaging publics in discussions about it. All this has occurred despite the paucity of technical capacity to consciously geoengineer the climate.

Reasons for this activity seem apparent: the risks and uncertainties of trying to manipulate the global climate through conscious technological intervention are enormous. Scientists are quite reasonably uninterested in shouldering the burden of these risks and uncertainties alone. Many scientists have proven more than willing to share this burden with policy makers and even the public.

Yet a strong, countervailing force has been afoot. This force is conspicuously present in the allocation of huge intellectual, technological, and financial resources to advancing scientific knowledge about climate change, and especially to predicting the future evolution of the climate. Here scientists promised that research would reduce uncertainties and predict the future of human activity on the behavior of the atmosphere as a foundation for subsequent policy decisions. The idea was obvious and largely uncontested: Fundamental scientific understanding

[22] See, for example, Stilgoe et al. 2013.

aimed at a predictive understanding of anthropogenic climate change will motivate governments to intervene through public policies that will reduce the consequences of climate change, mostly by reducing greenhouse gases emissions.[23] And while the uncertainties of climate change science are now a fervid political battleground, a larger point is generally neglected: Regardless of how certain scientists are about climate change, the future risks and uncertainties of trying to manipulate the global climate through policy action are no less enormous or daunting than they are with geoengineering—they are just different.

The larger contrast here that we want to emphasize is between prediction that depends on conventional (if discredited) notions of "rational" decision making - predict the future of human impacts on climate, then act on the basis of those predictions[24] - and an anticipatory approach that sees the future not as something that can be predicted but as something to be made through encounters among pluralistic worldviews, political action, technological change, and so on. What anticipatory governance does is try to condense and make explicit some of those encounters, in the context of decisions around the evolution of a particular technology or technological system.

We offer this contrast to make a key point about both geoengineering and anticipatory governance. Interminable and largely counterproductive political debates around climate change policy have been stunningly detached from consideration of the actual impacts of such policies on the future of climate.[25] Perhaps this detachment is because the causal chains from economic and policy incentives to reduced use of fossil fuels to mitigated climate risks are too complex, attenuated, and uncertain to provide good boundaries for arguments about climate policy. As Pielke et al. (2000) discussed, there is no "big knob" for dialing down climate impacts to some specified level through particular policy interventions. Geoengineering, in stark contrast, grabs attention precisely because the very idea (whether plausible or mere folly) posits a direct link between a fairly constrained set of actions and a climatic consequence.

To be clear, we are not offering a brief on behalf of geoengineering, but rather on behalf of the possible salutary effects of the anticipatory governance of geoengineering on the climate debate more broadly. Anticipatory governance provides a set of tools for focusing that attention in ways that are unavailable in the larger climate change discourses. The idea of geoengineering technologies disciplines the public and the scientific imagination in a way that predictive science cannot.

Anticipatory Governance as an Evaluative Tool

In addition to providing strategic vision, anticipatory governance can be an evaluative tool, using criteria derived from its

[23] See for example Pielke 1995; Meyer 2011.
[24] See for example Lempert et al. 2004.
[25] See for example Sarewitz and Pielke 2008

normative perspective.[26] Here we evaluate the processes and recommendations of five efforts to explore geoengineering governance that issued written reports published in 2009-2010. These reports occurred in a moment of time when the governance issues of geoengineering were taken up and deliberated by diverse stakeholders. This timeframe offered a window of opportunity for the concepts of anticipatory governance to affect changes in issue framing and decision-making. We ask the following questions drawn from the anticipatory governance approach about the processes that created the reports:

(i) Foresight – What influenced considerations of the future? What methods were used and how did this framing influence the process?

(ii) Engagement – Who was engaged? Whose interests were represented? How transparent were the proceedings?

(iii) Integration – Were diverse knowledge types, e.g. social and natural sciences or policy and engineering, integrated in the process?

(iv) Ensemblization - Were steps taken to harmonize these three elements throughout process?

We then evaluate the reports' recommendations:

- To what extent does the report adopt an anticipatory (rather than predictive) disposition toward the future?
- To what extent does the governance proposal involve substantive engagement with publics?
- Is engagement considered to be traditional science communication to fill the knowledge deficit of the public or to shape research agendas and inform scientific inquiry?
- To what extent does it attempt the integration of knowledge across disciplinary (and other) divides?
- Is the approach to integration hierarchical, separate but equal, or mutually collaborative?
- To what extent are these capacities brought together (e.g., such that anticipatory activities are also well integrated and participatory)?

Our analysis looks primarily for high-level policy goals and secondarily for demonstrations of "on-the-ground" mechanisms to operationalize these policies. Both are required, of course, because high-level policy goals can be on target, for example, while the specific instructions for implementation are inadequate or contradict the goals. Specific articulations suggest how the policy goals will be interpreted and, thus, implemented.

Efforts toward Governance of Geoengineering

The Royal Society produced *Geoengineering the Climate: Science, Governance and Uncertainty* in September 2009. It is chronologically the first report, and its influence is evidenced by the direct citations in the other four reports (see Table 1). The Royal Society's report defined geoengineering as "deliberate large-scale intervention in the Earth's climate system, in order to moder-

[26] Barben et al. 2008.

ate global warming".[27] The report sought to clarify "scientific and technical aspects of geoengineering" with an aim to contribute "to debates on climate policy".[28] The Royal Society defined two mechanisms for geoengineering: carbon dioxide removal (CDR) and solar radiation management (SRM).

The UK House of Commons-Science and Technology Committee (HOC-STC) issued *The Regulation of Geoengineering: Fifth Report of Session 2009-10* with the explicit goal of addressing three regulatory-focused questions for the agencies administered by the Prime Ministers and Government ministers. The HOC-STC adopted the terminology and definitions offered by the Royal Society. The HOC-STC and the US Government Accountability Office (GAO) formed a bilateral international collaboration to generate complementary reports on geoengineering governance. As shown in Table 1, there is evidence of cross-referencing between the HOC-STC and GAO reports.

The GAO report, *Climate Change: A Coordinated Strategy could Focus Federal Geoengineering Research and Inform Governance Efforts,* adopted the Royal Society's definition, but highlighted the uncertainty and complexity in defining geoengineering, for "without the guidance of an operational definition … agencies may not recognize or be able to report the full extent of potentially relevant research activities".[29] The GAO report, requested by the Chairman of Committee on Science, Technology in the House of Representatives, investigated the state of the science, the current efforts of the U.S. in geoengineering, and views of experts on the regulation and governance.

The US-based Bipartisan Policy Council (BPC) issued *Geoengineering: A National Strategic Plan for Research on the Potential Effectiveness, Feasibility, and Consequences of Climate Remediation Technologies* to build upon work by the National Academies of Sciences (2009). The BPC report explicitly avoided the term geoengineering, preferring "climate remediation" to describe, "technologies that are intentionally designed to counteract the climate effects of past greenhouse gas emissions to the atmosphere".[30] The BPC report references CDR and SRM to enact climate remediation.[31] It offers an initial strategy for the U.S. government to "go about improving its understanding of climate remediation options and how it should work with other countries to foster procedures for research [and] is offered as an exploration of what might be appropriate responses to changes in the global climate measured in recent decades".[32]

The Climate Institute Asilomar Group (CIAG) issued *The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques* for the scientific community as well as for gov-

[27] Royal Society 2009, ix
[28] Royal Society 2009, v
[29] GAO 2010, 23
[30] BPC, 2010, p. 3
[31] BPC 2010
[32] BPC 2010, 3-4

ernments and civil society world-wide. The goal was to "initiate a broad, interdisciplinary dialogue among experts that would produce guidance for the scientific community to responsibly and safely develop, test, and evaluate the potential for intentional intervention in the climate system [and] provide input for consideration of necessary and optimal mechanisms for planning, conducting, and overseeing scientific research".[33] The CIAG used the term *climate engineering* to "refer to activities taken to counter balance global warming and its impacts"[34] and described *remediation technologies* in reference to CDR and *intervention technologies* for atmospheric alterations, such as SRM.

	Royal Society	HOC-STC	GAO	BPC	CIAG	Influenced (Total)
Royal Society	X	0	0	0	0	0
HOC-STC	93	X	13	0	1	107
GAO	33	2	X	0	2	37
BPC	3	0	1	X	0	4
CIAG	9	1	7	0	X	17
Influential (Total)	136	3	21	0	3	

Table 1. The cross-influence between selected geoengineering reports. Reports listed in the left column are in chronological order. Direct references or testimonies from other reports are tabulated along each row. The bottom row shows the total instances that a report was referenced, a measure of its influence on the other reports. The right column sums instances in which a report relied on another, a measure of how it was influenced.

[33] CIAG 2010, 14
[34] CIAG 2010, 12

Process Evaluation

This section presents our process evaluation of the five reports. Overall, the processes that led to the reports range from the small, exclusive BPC group to the more than 165 participants at the Asilomar conference. Each considered the future implications of climate change as the driving force behind their work, and several addressed future societal dynamics. The BPC and HOC-STC processes integrated diverse knowledge types, suggesting awareness that each can benefit from the other, what we term here "mutually supportive," while the Royal Society and CIAG attribute equal value to different knowledge types but do not seek to integrate them. The GAO process was so opaque that it was not possible to discern how diverse knowledge was integrated. Each struggled to blend ("ensemblize") foresight, engagement, and integration.

Royal Society: *Geoengineering the Climate*
John Shepherd, Fellow of the Royal Society and Professorial Research Fellow in Earth System Science at the University of South Hampton, led the 11 member-working group. A four-member science policy team and a seven-member review panel supported the working group. The report's predisposition to the future technology made explicit reference to the "technology control dilemma".[35] Public statements from 51 individuals and 26 organizations illustrates the representation of contributors (see Table 2). The responses to the public call are available at an online repository[36]. The report integrated a diversity of disciplinary knowledge that we characterize, as separate but equal. The report's structure reinforces separation between technical and social issues. As such, the sections sometimes take contradictory stances, exemplified by a focus on modeling in the introduction that stands in contrast to the 'control dilemma' expressed in section 4.2. While the three elements of anticipatory governance are present, they are uncoordinated.

HOC-STC: *The Regulation of Geoengineering*
MP Mr. Phil Willis chaired the HOC-STC (see Table 2). Geoengineering was framed as 'Plan B' to climate change mitigation and adaptation. Societal dynamics are implicit, at best, in the discussion of regulatory responses. Expert testimony at both ends of the pro-con spectrum contributed evidence. Moderate social scientists and climatologists offered oral testimony and integrated comments on all topics of the inquiry. However, the report separates out these topics. The report's recommendations attempt to harmonize elements of anticipatory governance.

GAO: *Climate Change: Geoengineering Research*
Frank Rusco, director of GAO's Natural Resources and Environment division and staffers compiled the report with input from agency and domain experts (see Table 2). The lack of scientific certainty as something to be solved was the focus, thus adopting a "normal science" perspective, in contrast to our view of geoengineering as inescapably "post-normal." Minor attention was paid to societal dynamics in the section on political, economic and ethical concerns. The report uses 'experts' to mask attribution from specific persons. There was no public solicitation for contribution. A diversity of disciplines offered testimony, but testimony was segregated to specific topics. There is little evi-

[35] Collingridge 1980 as cited in Royal Society 2009, 37
[36] Consultative Responses are accessible at https://royalsociety.org/policy/publications/2009/geoengineering-climate/

dence that the three components of anticipatory governance are considered together.

BPC: *Climate Remediation*
Jane Long, associate director-at-large of Lawrence Livermore National Laboratory and Stephen Rademaker, former Assistant Secretary of State, co-chaired the task force. The task force took a predisposition to future technological, scientific and societal dynamics. Meetings were only open to invited parties, yet the report is publically available and a press conference was held. The task force integrated knowledge from a wide diversity of perspectives. Contributions were collaborative in the introduction and conclusion with specific topics reported in the report's body. Authorship was collaborative, and the recommendations indicate group consensus, but the group's deliberations were often contentious, illustrating challenges to bringing elements of anticipatory governance together harmoniously.

CIAG: *Climate Engineering*
Michael MacCracken, Chief scientist for Climate Change Programs at the Climate Institute with twenty-five years building climate change models led 13 members of the Asilomar Scientific Organizing Committee. The meeting's framing created a knowledge-first approach to climate engineering, expressed throughout the report. Conference organizers' invited a diversity of experts who revised a conference statement in an attempt to integrate the diverse perspectives, yet the agenda reflects a segregation of knowledge domains.

		Royal Society	HOC-STC	USGAO	Asilomar	BPC
Engagement	Author	J. Shepherd & 11 members	P. Willis & 13 members	F. Rusco & 16 Staff	M. MacCracken & 13 members	J. Long & S. Rademaker & 16 members
	Gender Ratio(M:F)	9:3	12:2	9:8	13:1	17:1
	Transparency	All material public	All material public	Testimony private, no attribution in text	Testimony private, attribution in text	Closed meetings, report open access.
	Public	Yes = n14	Yes = n2	No	No	No
	NGO	Yes = n11	Yes = n1	Yes = n2	Yes = n25	Yes = n3
	Media	No	No	No	Yes = n18	No
	Corporate	Yes = n5	No	No	Yes = n13	Yes = n1
	Academic	Yes = n35	Yes = n8	Yes = n9	Yes = n84	Yes = n9
	Government	Yes = n12	Yes = n2	Yes = n13 agencies	Yes =n31	Yes =n 5
	Legal Advisors (non-academic)	Yes = n4	No	No	Yes = n4	No
	Private Investor	No	No	No	Yes = n8	No
Foresight	Predisposed to future, if so how?	Yes, "Anticipating in the early stages how a technology will evolve is difficult" (p. 37).	Yes, "as part of a portfolio of responses to climate change" (p. 6).	Yes, Lack of scientific knowledge creates uncertainty. This needs to be resolved.	Yes, positioned to build upon previous reports.	Yes, "parameters must change over time as understanding of the risks of climate remediation evolves" (p. 3).
	Societal Dynamics	Yes, addresses the "reversibility of society's commitment to a technology" (p. 37).	Yes, but implicitly within the framing of regulatory needs.	Yes, addressed in section on Political, Economic, and ethical concerns	No, "understand potential responses to […] more completely" (p. 4).	
Integration	**Integration Diverse**	Yes, "geoengineering will be determined as much by social, legal and political issues as by scientific and technical factors."	Yes, contributions are integrated with social scientists and climatologists commenting on all topics of the inquiry.	No, expert testimony integrated by GAO Staff, not entirely transparent process.	Yes, "Their expertise covered Earth, environmental, and social sciences, risk assessment, public policy, ethics, philosophy, history, economics" (p. 7).	Yes, "scientific, science policy, foreign policy, national security, legal, and environmental communities … a wide range of perspectives and expertise to the task force" (p. 2).
	Form	**Separate but Equal**	**Mutually Supportive**	**Unknown**	**Separate but Equal**	**Mutually Supportive**
Ensemblization		No, segmentation of key concepts	Recommendations present a list of mutually supportive activities	No, segmentation of key concepts	No, division of labor among expert groups	Collaborative authorship, but not uncontested and harmonious

Table 2. Report process analyzed with Anticipatory Governance

Evaluating Recommendations with Anticipatory Governance

Evaluating the reports' recommendations against anticipatory governance, we find that all five articulate foresight, engagement and integration as high-level principles. However, three of the reports express foresight as enhanced prediction, engagement as traditional science communication, and integration as either hierarchical or separate but equal. As such they stand at odds with our view of anticipatory governance. The Royal Society and CIAG elicited broad representation of views and diverse knowledge types during their respective processes, yet neither articulates core concepts from anticipatory governance in the specific recommendations. At the other end of the spectrum, the BPC report is the most exclusive and least open process, and yet its recommendations articulated each and every aspect of anticipatory governance, thus putting processes at odds with the outcomes.

Royal Society: *Geoengineering the Climate*

The Royal Society report expresses the elements of anticipatory governance at a high-level, but calls for prediction (and not exploratory foresight), science communication and dialogic public engagement (an internal inconsistency), and separate but equal (and not collaborative) work between the natural and social sciences (see Table 3). The Royal Society articulates the highest priority for foresight is in predictive models of Earth's climate, "unintended environmental effects should be carefully assessed using improved climate models as well as the best now available"[37] and "detailed modeling of their impacts on all aspects of climate (including precipitation patterns and monsoons) is needed".[38] The Royal Society certainly addresses engagement as a guiding principle for the governance of geoengineering in the form of "stakeholder engagement and a public dialogue process" as a high level goal.[39] The principle is upheld in certain statements such as, "diverse publics and civil society groups could play a much more positive and substantive role in the development of the field, by contributing to analysis of the social, ethical and equity basis of geoengineering proposals".[40] But engagement does not extend beyond the social sciences, as "[p]olicymakers need well-informed and authoritative advice based on sound science," contradicting the goal of public engagement[41] and thus demonstrating internal inconsistencies in the report. There is evidence of integrating diverse knowledge into the report, yet these efforts keep things separate but equal, at best. The Royal Society advocates for "an international body such as the UN Commission for Sustainable Development" to lead the governance regime. There is little evidence supporting the ensemblization of foresight, engagement, and integration for governance. The reliance is on clearly dividing labor and minimizing feedback or cross-cutting approaches.

HOC-STC: *The Regulation of Geoengineering*

The HOC-STC's recommendations address the core elements of anticipatory governance at a high level, and its specifics call for exploratory foresight and substantive engagement; nevertheless, knowledge integration remains separate but equal and not collaborative (see Table 3). The report explores future

[37] Royal Society 2009, x

[38] Royal Society 2009, xi

[39] Royal Society 2009, xi

[40] Royal Society 2009, 42

[41] Royal Society 2009, 6

regulations and calls for something between moratoria and determinism. For example, "geoengineering is not sufficiently advanced to make the technology predictable, but this itself is not grounds for refusing to develop regulatory frameworks or for banning it".[42] Particular attention is paid to engagement by the report and reiterated in five specific recommendations. The report calls for a proactive approach to governance. However, the integration of diverse knowledge remains separate but equal, as "[d]ecisions [are] to be based on the best scientific evidence, including social science".[43] The report suggests the United Nations Framework Convention on Climate Change should be the organizing regulatory body. Elements of anticipatory governance are considered in isolation.

GAO: *Climate Change: Geoengineering research*
The GAO's recommendations attend to anticipatory governance at a high-level, but the specifics call for predictive foresight (and not exploratory), science communication (and not engagement), and separate but equal (and not collaborative; see Table 3). The report foresees that geoengineering "may have unintended and significant impacts within and beyond national borders"[44], but it seeks predictive models to address uncertainties and "inform societal debate and decision-making over what would constitute a 'climate emergency' and whether deployment of a geoengineering approach would be merited".[45] There are calls for public engagement throughout the GAO report, but the specifics are off base: "Answers to these [unresolved scientific questions] will also inform the public debate".[46] Diverse knowledge is integrated into the report, but there is a clear hierarchy in the prioritization of certain knowledge, "**Better understanding of the climate and a way to determine when a "climate emergency is reached"**".[47] The GAO adopts the National Research Council's recommendation for "basic climate science research, including (1) improved detection and attribution of climate change to distinguish the effects of intentional intervention in the climate system from other causes of climate change, and (2) information on climate system thresholds, reversibility, and abrupt changes".[48] The GAO advises that the US Office of Science and Technology Policy (OSTP) coordinate federal research, but the report's representation of engagement, foresight and integration does not suggest any ensemblization.

BPC: *Climate Remediation*
BPC's recommendations demonstrate the core elements of anticipatory governance at a high-level and, uniquely, in its specific recommendations. BPC calls for exploratory foresight, substantive engagement and mutually collaborative approaches to integration, (see Table 3). BPC recommends that OSTP coordinate federal research efforts, as it is "the only entity in the federal government in a position to realistically coordinate this research enterprise and navigate the technical and political challenges".[49] The BPC report recommends an exploratory approach to foresight. "The environmental, scientific, technological, and social context for climate remediation research is likely to evolve signif-

[42] HOC-STC 2010, 49
[43] HOC-STC 2010, 52
[44] GAO 2010, 16
[45] GAO 2010, 16
[46] GAO 2010, 38
[47] Bold in original, see GAO 2010, 16.
[48] GAO 2010, 16
[49] BPC 2010, 17

icantly over time in unpredictable ways. Federal research programs should be required to review those changing conditions on a regular basis”.[50] This quote also highlights the mutually supportive approach to integration. The report addresses engagement early on, as “climate remediation techniques will require new governance structures to engage the public and to set parameters”[51] and throughout the text, e.g., “Robust and durable mechanisms for public engagement should be established early in the research programs”.[52] The BPC report is peppered with references to knowledge integration and identifies other attempts that fail to do so, e.g., “There is also a clear need for a more extensive integration of social sciences than has been achieved so far under either the USGCRP [US Global Change Research Program] or USCCTP [US Climate Change Technology Program]”.[53]

CIAG: *Climate Engineering*

The Climate Institute’s report articulates anticipatory governance at a high-level, but the approach to foresight is predictive, engagement is secondary to scientific knowledge, and integration is separate but equal (see Table 3). Foresight is expressed as a means to predict future outcomes, e.g., “[n]umerical modeling studies of the range of approaches that could contribute to moderating climate change and its impacts”.[54] The report opens with the five Oxford principles including, “[p]ublic participation and consultation in research planning and oversight, assessments, and development of decision-making mechanisms”.[55] The report’s tenor suggests that laboratory and modeling activities require ‘business as usual’ approaches to governance and that by keeping dangerous technologies in the laboratory, society is assured safety. This perspective influences the approach to engagement, such that the public need not be involved until, “[f]or field experiments, the need for public consultation, like the need for other elements of legitimate governance, will increase with the scale and potential risks of the proposed research experiment”.[56] The demand for societal, ethical or legal aspects is not integrated (and actually excluded) from early stage scientific research and experimentation in the lab: “[m]odeling and laboratory studies pose little to no risk of impact to the climate, environment, or society, and so new governance mechanisms are not likely to be needed”.[57] This perspective reinforces the notion that it is fine for dangerous research to happen in the laboratory, i.e., keep the door closed to protect society, and restricts opportunities to open up the laboratory as a place to explore questions of societal or ethical implications through reflexive inquiry.[58] Yet, the laboratory is often identified as a space for those questions to arise earlier, rather than waiting for the science to emerge from the laboratory and then become subjected to ethical and societal inquiry. With respect to ensemblization, there is a strong tension between governance and impartiality, “a critical function of national and international governance systems must be to organize and manage competent, impartial, independent, and transparent expert assessments of the benefits and risks of proposed climate-engineering approaches”.[59] The report thus adopts the “normal science” risk-benefit par-

[50] BPC 2010, 14
[51] BPC 2010, 3
[52] BPC 2010, 14
[53] BPC 2010, 18
[54] CIAG 2010, 21
[55] CIAG 2010, 9
[56] CIAG 2010, 23
[57] CIAG 2010, 18
[58] Fisher 2014
[59] CIAG 2010, 22

adigm, which assumes that impartiality is practically and theoretically possible and that values are satisfactorily subject to quantification, even if, as seems likely, uncertainty remains high and values remain strongly contested.

	Engagement	Foresight	Integration	Ensemblization
Royal Society: *Geoengineering the climate*	Principle present: Yes Specifics aligned, **No**	Principle present: Yes **Predictive** Societal dynamics? **Yes**	Principle present: Yes **Separate but Equal**	Principle present: **No** Specifics aligned, **No**
HOC-STC: *The regulation of geoengineering*	Principle present: Yes Specifics aligned, **Yes**	Principle present: Yes **Exploratory** Societal dynamics? **Yes**	Principle present: Yes **Separate but equal**	Principle present: **No** Specifics aligned, **No**
GAO: *Climate Change: Geoengineering research*	Principle present: Yes Specifics aligned, **No**	Principle present: Yes **Predictive** Societal dynamics? **No**	Principle present: Yes **Hierarchy**	Principle present: Yes Specifics aligned, **No**
BPC: Climate Remediation	Principle present: Yes Specifics aligned, **Yes**	Principle present: Yes **Exploratory** Societal dynamics? **Yes**	Principle present: Yes **Mutually supportive**	Principle present: Yes Specifics aligned, **Yes**
Climate Institute: *Climate Engineering*	Principle present: Yes Specifics aligned, **No**	Principle present: Yes **Predictive** Societal dynamics? **No**	Principle present: Yes **Separate but equal**	Principle present: **No** Specifics aligned, **No**

Table 3. Report recommendations analyzed with Anticipatory Governance.

Discussion and Conclusion

The core concepts of anticipatory governance are permeating the science-policy dialogue in areas other than nanotechnology. Yet while the high-level goals stated in each report align with anticipatory governance, the specific articulations of the key concepts are rarely aligned. Our evaluation of each report's recommendations highlights areas of divergence from and convergence with anticipatory governance. Geoengineering might be simply a Rorschach test for entrenched positions on climate change. For example, calls for large, international geoengineering efforts by the Royal Society, HOC-STC, and CIAG reports seem to recapitulate the reliance on a dysfunctional global governance regime for climate change. Alternatively, geoengineering is positioned as a 'Plan B' made necessary by the apparent intractability of climate change when viewed as a collective action problem. All five reports attend to both CDR and SRM techniques, yet most concerns focus on SRM, as it is "high leverage"- meaning faster and less expensive to deploy. The reports often frame planning for the future as a response to the implications of climate change, rather than about what we want the future to be and what options are open to complex societies navigating an uncertain future. These forums might have been a great opportunity to deliberate on how to understand the relations between human prospects and changing climatic conditions, rather than suggesting that pre-industrial conditions are 'natural' and thus desirable.

Some scientists are demonstrating a willingness to share the burden of governance with industry, policy makers, and the public. For example the Climate Institute's Asilomar report states, "climate engineering would be much more than a purely scientific decision".[60] However, many scientists argue for the status quo i.e. no or minimal oversight for laboratory research, even if risky outcomes or technologies are imminent. This notion is exemplified as, "Modeling and laboratory studies pose little to no risk of impact to the climate, environment, or society, and so new governance mechanisms are not likely to be needed".[61] In such cases, certain scientists want to assume the responsibility for keeping dangerous knowledge and technology in the laboratory, safe from society, rather than opening up to reflexive questions regarding the nature and intent of the research. Yet, if scientists are explicit in wanting to share the risks of geoengineering governance with broader constituencies, a question left implicit is whether there are experiments that are better left undone, and if so, who should get to answer. A fundamental challenge remains, how to bypass the "knowledge first" approach and initiate engagement to proactively explore broader public values.

There is a tension between the process that created the reports and their recommendations. BPC was perhaps the least transparent and inclusive of those investigated, more closed, it seems, than the Royal Society. Nevertheless, BPC's recommendations are most directly aligned with anticipatory governance. Any reflective approach would not abandon the integrity of the process so quickly simply upon seeing such results. The obvious explanation is not only that one of this paper's authors (Sarewitz) was on the small BPC task force, but as well that that group included a number of members who were highly attuned to the value of public deliberation and the limits of normal science in addressing complex socio-technical problems *and* that BPC deliberations did not explicitly privilege natural science expertise over social science. At Asilomar, in contrast, the number of participants and privilege to natural scientists may actually have acted against adopting a mutually supportive approach to knowledge integration. Perhaps the broad representation at Asilomar created a paper-thin smattering of alternative perspectives, thus leaving MacCracken and the Asilomar Scientific Organizing Committee the unenviable task of marrying a hodgepodge of perspectives with a less insistent demand for a unified, integral whole than was present at BPC and its focus on consensus.

Each report calls for public involvement, yet the capacity to conduct such involvement in an international setting is meager. The international governance process employed for

[60] CIAG 2010, 22
[61] CIAG 2010, 18

climate change, to date, is characterized as dysfunctional.[62] These five reports highlight complications for engagement between two of the wealthiest and most technologically advanced societies (US and UK). The first recommendation listed in the HOC-STC report is: "We welcome the review that the House is carrying out of the audio-visual facilities in committee rooms to enable the taking of oral evidence in committee by video link." We cannot reasonably expect to engage in a global dialogue if the House of Commons struggled to video-conference with one person (even five years ago). Thus, challenges to global engagement highlights both social challenges with an approach lodged in global governance, as well as for the communications systems for international debate and dialogue that supports it. One possible model for broader participation is the World Wide Views process, organized by the Danish Board on Technology, which conducted public engagements for global warming in 2009[63] and biodiversity in 2012[64] at numerous sites around the globe. This approach is still rough around the edges, especially in eliciting public values, and has little capacity to translate findings into action or even high-level dialogue.

Several of the reports aspire to creating predictive models so accurate that we might predict the next rain cloud to appear over Eeyore's head, and yet there is no clear sense in which such certainty is inevitable, or if inevitable then timely, or if timely then even helpful in resolving governance issues. Only by avoiding the 'knowledge first trap' when anticipating risks[65] can we do our best to assure that knowledge creation is responsive to governing needs and that governance issues get the attention they deserve from the start.

The concept of knowledge integration, while apparent in all three reports, remains largely in the realm of 'separate but equal' – which is even in this analogy inherently unequal. The division of labor is clear – natural scientists will discover the wonders of nature and social scientists will uncover, later, if people like the discovery. Rather than ascribing to a division of labor there are efforts to integrate diverse knowledge types to create usable research for policymakers, which is designed to serve the public good from the start. This type of approach is exemplified in recent testimony to the Presidential Commission for the Study of Bioethical Issues on early integration between social and natural sciences within the Brain Initiative.[66] There is much work to be done, conceptually and practically, to understand how science and technology can advance the 'public good' without creating unacceptable trade-offs. To this end, we suggest that normative anchors exist, e.g. human rights, distributive justice, and sustainability, to which geoengineering discourses must remain explicitly moored.[67] Specifying the societal goals for those actively pursuing geoengineering research would provide an alternative evaluation scheme or a new mechanism to assess 'progress'. Such a scheme would help prevent geoengineering from being captured either by experts acting within an inappropriate normal science paradigm, or by states or even private entities with narrow views of risks and benefits. An-

[62] Bodansky 2013
[63] Chhetri and Grossman 2012
[64] Chhetri and Farooque 2012
[65] Brown 2009
[66] Fisher 2014
[67] von Schomberg 2013; van den Hoven 2013

ticipatory governance provides a framework for embedding such normative anchors in a deliberative and inclusive process that recognizes expertise—of many sorts—as not only input for, but also subject to, the collective learning that society needs to undertake to wisely govern geoengineering.

Our evaluation of five reports on geoengineering governance identifies gaps in their various approaches to foresight, engagement, and integration. There continues to be a predictive approach—we would term it a predictive fallacy— that views action as best supported through more realistic and detailed models, rather than through an exploratory approach that asks what society desires for the future, and accepts that futures are made step-by-step, rather than predicted and then achieved. Public involvement is often cast as means to educate the masses in the hope that more knowledge equates with better decisions, rather than engaging in value-based deliberation and pluralistic decision-making. Inter- and trans-disciplinary knowledge integration is challenged by the specialization of labor between social and natural scientists and between knowledge producers and decision-makers.

We offer anticipatory governance as a vision for growing the civic capacity to guide the emergence of novel technologies. Its principles are observed in each of the five reports reviewed, and yet those high-level principles are not systematically supported by specific recommendations that contribute to building this capacity. Nonetheless, the very fact that such efforts have emerged around the governance of geoengineering research and that the principals are honored, if sometimes in the breach, in such disparate efforts, suggests to us that a social capacity to wisely govern powerful emerging technologies may itself now be emerging. Indeed, we suspect that geoengineering's combination of uncertainty, logic and scariness are motivating an awareness among both expert and activist communities that the normal science and risk paradigms are unequal to the governance task at hand. If anticipatory governance had not already been invented, now, it appears, would be the time to do so.

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