MORATORIA FOR GLOBAL GOVERNANCE AND CONTESTED TECHNOLOGY:
THE CASE OF CLIMATE ENGINEERING

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ABSTRACT

Calls for moratoria are a frequent response to controversial issues in international diplomacy and control of technology, and are now prominent in debates over governance challenges posed by climate engineering (CE) – intentional modification of the global climate to reduce changes caused by human emissions of greenhouse gases. Based on twelve historical cases of moratoria in other areas of diplomatic conflict or controversial science and technology, we present a novel analytic framework to examine purposes, design characteristics, and conditions for effectiveness of moratoria, based on a taxonomy of three ideal moratorium types: risk-management moratoria, principled-conflict moratoria, and bargaining moratoria. We use this framework to examine potential contributions and design conditions for a moratorium on CE. A moratorium for CE could seek primarily to advance risk-management aims or bargaining aims, with distinct implications for its timing, scope, associated actors, and conditions for termination. Beyond the current, high-stakes case of CE, the proposed analytic framework has broader implications for critical examination of moratorium proposals, current and future, in other areas of controversial research, technology, and governance challenges.

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INTRODUCTION

As projections of climate change grow more severe, the responses available to manage the resultant impacts appear increasingly weak and slow in effect. Deep cuts in global greenhouse-gas emissions, which require moving the world economy away from fossil fuels, are both essential and feasible, but little progress has yet been achieved. Even extreme emission cuts would take decades to stop or significantly slow climate change.[1] Adaptation measures to reduce vulnerability of societies and ecosystems are also essential, but as yet minimally developed. Both these approaches are necessary, but relative to the changes required, neither can be quick, cheap, or fully curative.

In view of these limits, there is increasing interest in a third type of response, climate engineering (CE)—intentional modification of the global climate system to reduce or slow climate change.[2] A wide range of CE methods are identified, which either remove carbon dioxide from the atmosphere or alter the Earth's radiation balance. Some methods appear able to reduce global heating rapidly, at shockingly low cost. A decision to actively manage the global climate with CE would represent a monumental step for human societies, and would raise equally monumental risks, controversies, and governance challenges. While decisions about operational deployment of CE appear to lie some decades in the future, a contentious debate is already underway over whether, and with what restrictions, to pursue CE research.[3]

Many commentators argue that expanded CE research is needed for informed decision-making.[4] All formal assessment bodies that have considered the issue agree, but have not considered how near-term research decisions might subtly influence high-stakes, longer-term questions of CE gov-

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[1] *See infra* Part I.

[2] COMM. ON GEOENGINEERING CLIMATE, NAT'L RESEARCH COUNCIL, CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION pg.# (2015); COMM. ON GEOENGINEERING CLIMATE, NAT'L RESEARCH COUNCIL, CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH pg.# (2015); JOHN SHEPHERD ET AL., POLICY REPORT OF THE ROYAL SOC'Y, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY 1 (2009). The 2015 reports of the National Research Council (NRC) will hereinafter be labeled as "2015 NRC REPORTS."

[3] *See infra* Part I.A.

[4] *See, e.g.*, M. Granger Morgan, Robert R. Nordhaus & Paul Gottlieb, *Needed: Research Guidelines for Solar Radiation Management*, 2013 ISSUES IN SCI. & TECH. 37, 41, http://www.vnf.com/2026; David W. Keith, Edward Parson & M. Granger Morgan, *Research on Global Sun Block Needed Now*, Opinion, 463 NATURE 426, __ (2010); Edward A. Parson & David W. Keith, *End the Deadlock on Governance of Geoengineering Research*, 339 SCI. 1278, ___ (2013).

ernance or use.[5] Other commentators object that reckless or destructive use of CE could bring harms worse than anything projected from climate change; that any large-scale deployment would risk significant environmental and societal harms; and on that basis, oppose most or all research as encouraging a foreseeably destructive activity.[6] Research funders, pressed from both sides, have thus far avoided significant programmatic commitments to CE research.[7] Yet a few small experiments have proceeded, via some combination of private or unrestricted funding, regulatory ambiguity, and concealment of intentions.[8] Absent legitimate public research programs, these isolated experiments have largely served to arouse opposition from groups seeking strict restrictions on CE, while offering at best small advances in understanding.[9]

In the context of prolonged controversy over CE, proposals to adopt a moratorium have emerged as a prominent theme of the debate. We have identified eighteen moratorium proposals, advanced by diverse actors (scientists, lawyers, academics, environmental non-governmental organizations (NGOs), former government officials, and think-tanks) whose views on CE span the debate from categorical opposition to cautious conditional support.

These proposals call on scientists, funders, or governments to suspend certain CE-related activities until certain conditions are met.[10] Beyond that broad commonality, the proposals are variable, ambiguous, or incomplete in details, and most lack explicit statements of what benefits the proposed moratorium would achieve or how. In view of this confusion, the emerging focus on a potential CE moratorium has thus far contributed little to advancing broader debate on whether and how to pursue CE research, how to govern potential future proposals for operational CE, and what the relationship should be between CE and the broader climate-change agenda.

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[5] 2015 NRC REPORTS, *supra* note 2, at pg.#; SOLAR RADIATION MGMT. GOVERNANCE INITIATIVE [SRMGI], SOLAR RADIATION MANAGEMENT: THE GOVERNANCE OF RESEARCH __ (2011), *available at* http://www.srmgi.org/report/; JANE LONG ET AL., TASK FORCE ON CLIMATE REMEDIATION RESEARCH, BIPARTISAN POLICY CTR., GEOENGINEERING: A NATIONAL STRATEGIC PLAN FOR RESEARCH ON THE POTENTIAL EFFECTIVENESS, FEASIBILITY, AND CONSEQUENCES OF CLIMATE REMEDIATION TECHNOLOGIES pg.# (2011) [hereinafter BPC RPT.]; SHEPHERD ET AL., *supra* note 2, at __.

[6] *See infra* text accompanying notes __-__.

[7] *See infra* Part I.B.

[8] *See infra* text accompanying notes __-__.

[9] *See,* e.g., *A Charter for Geoengineering*, Editorial, 485 NATURE 415, 415 (2012); Benjamin Hale & Lisa Dilling, *Geoengineering, Ocean Fertilization, and the Problem of Permissible Pollution*, 36 SCI. TECH. & HUMAN VALUES 190, 4 (2011).

[10] *See infra* Part II.

We have two aims, one specific and topical, one general and conceptual. Our specific aim is to advance understanding of the potential role of a moratorium in contributing to effective and prudent control of CE: what purpose could a moratorium serve, under what conditions and with what risks? To this end, we review historical experience with moratoria in other relevant decision areas, and the existing literature, to extract principles and insights of relevance to CE. The literature on moratoria, however, is strikingly thin, marked by limited empirical foundations and substantial conceptual and definitional confusion.[11] This deficiency spurred our broader conceptual aim, to develop a general analytic framework to understand moratorium purposes, design characteristics, and conditions for effectiveness across issues.

Part I introduces CE, how it emerged in the climate debate, and the major controversies over its development and use. Part II introduces the concept of a moratorium, the characteristics that define one, and the moratorium proposals advanced for CE. Part III reviews twelve historical cases of moratoria in international diplomacy and controversial science and technology. Part IV proposes a taxonomy of three ideal types of moratorium, based on their primary purpose and decision context: moratoria for risk assessment and management, moratoria as landmarks in principled conflicts, and moratoria as tactical bargaining aids to help reach mutually advantageous agreements. This taxonomy provides a basis for analysis of moratorium characteristics, mechanisms of influence, and effects. Part V applies these insights to what may well be the most important moratorium in human history, one on CE research or implementation. Part VI provides our major conclusions, as they pertain to a moratorium for CE and to moratoria in general.

I. CLIMATE ENGINEERING RESEARCH, USE, AND GOVERNANCE

Over the past two centuries, emissions of carbon dioxide (CO_2) and other greenhouse gases have raised the atmospheric concentration of these gases and altered the Earth's climate and ocean chemistry.[12] The results are evident in higher surface and ocean temperatures, rising sea levels, increased extreme weather events, and changes in precipitation patterns, with

[11] *See id*.

[12] WORKING GRP. I, CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [IPCC], CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 4, 11-15 (T.F. Stocker et al. eds., 2013) [hereinafter IPCC, WORKING GRP. I], *available at* http://www.ipcc.ch/report/ar5/.

diverse and mostly adverse ecological and socioeconomic impacts.[13]

Slowing and stopping climate change will require extreme cuts in greenhouse-gas emissions. The global energy transition needed to achieve these cuts is a feasible challenge,[14] even if the feasibility of specific temperature targets such as 2 or 1.5 degrees may be doubtful.[15] Recognizing the international nature of this challenge, governments adopted the U.N. Framework Convention on Climate Change (UNFCCC) in 1992.[16] Yet through two decades of negotiations, disputes over cost, feasibility, and shared responsibility have obstructed meaningful actions and emissions have continued to rise.[17] Some national and sub-national governments have adopted policies to reduce emissions, but with few exceptions these have been weak and ineffectual.[18] Even if extreme emission-cutting measures are adopted, inertia in the climate and energy systems will delay climate stabilization for decades.[19]

As prospects for limiting near-term risks through emission cuts have weakened, there has been growing attention to other responses, including adaptation measures to reduce vulnerability to climate change, and also climate engineering (CE): intentional modification of the global climate to reduce or slow changes from elevated greenhouse gases.[20] The concept of CE is contested, in its desirability and even its proper characterization, as suggested by the range of names proposed for it, which also include "geoengi-

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13 WORKING GRP. II, CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY 6-7, 12 (Christopher B. Field et al. eds., 2014) [hereinafter IPCC, WORKING GRP. II], *available at* http://www.ipcc.ch/report/ar5/wg2/.

14 *See generally* WORKING GRP. III, CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2014: MITIGATION OF CLIMATE CHANGE ch. 6 (O. Edenhofer et al. eds., 2014) [hereinafter IPCC, WORKING GRP. III], *available at* http://www.ipcc.ch/report/ar5/. *See also id.* at ch. 6.3.

15 UNITED NATIONS [UN] FRAMEWORK CONVENTION ON CLIMATE CHANGE, REPORT OF THE CONFERENCE OF PARTIES ON ITS TWENTY-FIRST SESSION pg.# (2016); David G. Victor and Charles F. Kennel, *Climate Policy: Ditch the 2°C Warming Goal*, Comment, 514 NATURE 30, pg.# (2014).

16 UN Framework Convention on Climate Change, art. 3(3), 1771 U.N.T.S. 107 (1992) [hereinafter UNFCCC].

17 *See generally* Michel G.J. den Elzen et al., *Countries' Contributions to Climate Change: Effect of Accounting for All Greenhouse Gases, Recent Trends, Basic Needs and Technological Progress*, 121 CLIMATIC CHANGE 397 (2013).

18 *See Tracking INDCs*, CLIMATE ACTION TRACKER, http://climateactiontracker.org/indcs.html (last visited Mar. 7, 2016).

19 *See generally* Nathan P. Gillett et al., *Ongoing Climate Change Following Complete Cessation of Carbon Dioxide Emissions*, 4 NATURE GEOSCIENCE 83 (2011).

20 *See supra* note 2.

neering,"[21] "climate remediation,"[22] "climate management,"[23] "climate intervention,"[24] and "earth systems management."[25] Although definitions vary in detail, they converge on two characteristics: CE is any intervention to modify climate that is: 1) *intentional*, and thus distinct from inadvertent changes caused by emissions, land-use change, or other human activities, and; 2) *large-scale,* aiming to modify climate over an extended period at continental to global scale, and thus distinct from local weather modification.[26]

CE interventions are of two types, distinguished by whether they change the Earth's carbon cycle or its radiation balance.[27] Carbon-based methods, or carbon dioxide removal (CDR), remove CO_2 from the atmosphere, offsetting increases from anthropogenic emissions. They achieve this either by enhancing natural carbon sinks such as forests, soils, or the ocean, or by capturing CO_2 directly from the air and placing it in stable reservoirs.[28] By removing atmospheric CO_2, CDR reduces all its impacts, but can only do so slowly. Given the large stock of CO_2 in the atmosphere, CDR aims to drain a bathtub through a straw: even with aggressive deployment, achieving large deflection of climate change would take decades.[29]

Radiation or sunlight methods alter the Earth's radiation balance, offsetting the heating caused by greenhouse gases. Most approaches make the Earth a little whiter to reflect more sunlight.[30] Proposed methods include spraying a mist of reflective droplets in the upper atmosphere; spraying seawater to brighten marine clouds; placing shields in space to block a little of the sun's disc; reducing cirrus clouds that, like greenhouse gases, impede the Earth's cooling;[31] and whitening the land surface, ocean, or built envi-

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[21] *See* Cesare Marchetti, *On Geoengineering and the CO_2 Problem*, 1 CLIMATIC CHANGE 59, pg.# (1977).

[22] *See* BPC REPORT, *supra* note 5, at 3.

[23] *See* Jay Michaelson, *Geoengineering and Climate Management: From Marginality to Inevitability*, 46 TULSA L. REV. 221, 225-28 (2010).

[24] *See* 2015 NRC REPORTS, *supra* note 2, at pg.#.

[25] *See generally* Brad Allenby, *Earth Systems Engineering and Management*, IEEE TECH. & SOC'Y MAG. 10 (2000/2001).

[26] *See* Ralph J. Cicerone, *Geoengineering: Encouraging Research and Overseeing Implementation*, Editorial, 77 CLIMATIC CHANGE 221, 221 (2006).

[27] SHEPHERD ET AL., *supra* note 2, at __.

[28] *See* Steven Chu, *Carbon Capture and Sequestration*, Editorial, 325 SCI. 1599 (2009).

[29] *See* IPCC, WORKING GRP. I, *supra* note 12, at 552.

[30] SHEPHERD ET AL., *supra* note 2, at __;

[31] T.Storelvmo, W.R.Boos, N.Herger, *Cirrus Cloud Seeding: a climate engineering mechanism with reduced side effects?* 372 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y, pg.# (2014).

ronment.[32] In contrast to CDR and emission cuts, some radiation methods can change the climate rapidly, cooling the Earth within a year or so,[33] but these methods cannot fully undo the harms of elevated greenhouse gases. They reverse temperature and precipitation changes only approximately, cannot reverse processes with slow dynamics such as loss of ice sheets,[34] and do nothing for non-climate effects such as ocean acidification.[35] In a characterization likely to remain valid with future advances, radiation methods have been described as "fast, cheap, and imperfect."[36]

Recent interest in CE is not discovery of a new idea, but re-emergence of an old one. Interest in weather modification dates to the early 1900s,[37] and CE was the first response discussed in discussions of climate change in the 1960s.[38] Yet CE received scant attention in policy debates that emerged in the 1990s.[39] A 2006 article by atmospheric scientist Paul Crutzen is credited with re-opening debate over CE and building support for research into its efficacy and risks.[40]

A. Major Points of Controversy over Climate Engineering

Both CDR and radiation methods are controversial, but the nature and severity of controversy differ between them. Consequently, there is disagreement whether to consider the two types together.[41] While we find their potential benefits and risks dissimilar enough to merit separate treatment in

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[32] *Id.* at __.

[33] *See* T.M. Lenton & N.E. Vaughan, *The Radiative Forcing Potential of Different Climate Geoengineering* Options, 9 ATMOSPHERIC CHEMISTRY & PHYSICS 5539, 5554 (2009).

[34] K.E. McCusker, D.S. Battisti, C.M. Bitz, *Inability of Stratospheric Sulfate Aerosol Injections to Preserve the West Antarctic Ice Sheet*, 42 GEOPHYSICAL RES. LETTERS 4989, pg.# (2015).

[35] *See generally* James C. Orr et al., *Anthropogenic Ocean Acidification Over the Twenty-First Century and its Impact on Calcifying Organisms*, 437 NATURE 681 (2005).

[36] Keith, Parson & Morgan, *supra* note 4, at 426.

[37] *See generally* JAMES RODGER FLEMING, FIXING THE SKY (2012).

[38] *See generally* PRESIDENT'S SCI. ADVISORY COMM., RESTORING THE QUALITY OF OUR ENVIRONMENT (1965); MAN'S IMPACT ON THE GLOBAL ENVIRONMENT (Carroll M. Wilson & William H. Matthews eds., 1970).

[39] *But see, e.g.*, David Keith & H. Dowlatabadi, *A Serious Look at Geoengineering*, 73 EOS TRANSACTIONS AM. GEOPHYSICAL UNION 289 (1992).

[40] Paul J. Crutzen, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?* 77 CLIMATIC CHANGE 211 (2006). *See also* Cicerone, *supra* note 26, at pg.#.

[41] *See* MEETING REPORT, IPCC EXPERT MEETING ON GEOENGINEERING pg.# (Ottmar Edenhofer et al eds., 2011), *available at* https://www.ipcc.ch/pdf/supporting-material/EM_GeoE_Meeting_Report_final.pdf; Clare Heyward, *Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change*, 46 POLITICAL SCI. & POL. 23, __ (2013).

risk assessments and policies, in this paper (except as noted) we treat the two together because our arguments about moratoria are relevant to both.

Controversies over CE mostly reflect the tension between its potential benefits and risks. Some radiation methods could slow or stop global heating rapidly in the event of severe climate-change impacts.[42] Radiation methods could also be valuable in the context of the required global energy transition, by slowing change while emissions are being cut or by targeting regional processes of global importance such as Arctic sea ice.[43] Radiation methods offer these benefits hundreds or thousands of times cheaper than achieving the same cooling—more slowly, but more durably—through emission cuts.[44]

CDR lacks the speed and cost advantages of radiation methods, but offers more flexibility than emission cuts—in how much CO_2 is removed, where, and when—and thus offers potential scale economies, synergies with other industrial processes, and environmental co-benefits.[45] Even a modest rate of CDR sustained for decades could help speed climate stabilization. Moreover, large-scale CDR offers the prospect of removing CO_2 faster than it is emitted, driving human emissions negative and reversing prior changes, and so allowing "overshoot" scenarios that temporarily exceed a target concentration then decline.[46]

All CE methods pose risks. In addition to residual risks from elevated greenhouse gases, particular radiation methods may disrupt the stratospheric ozone layer, increase acid deposition, alter regional weather patterns, or change the appearance of the sky.[47] CDR's risks mainly depend on where and how the captured carbon is disposed. They include disruption of ma-

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42 *See generally* N. Markusson et al., *'In Case of Emergency Press Here': Framing Geoengineering as a Response to Dangerous Climate Change*, 5 CLIMATE CHANGE 281 (2014).

43 *See generally* Michael C. MacCracken, *On the Possible Use of Geoengineering to Moderate Specific Climate Change Impacts*, 4 ENVTL. RES. LETTERS 45107 (2009).

44 J. McClellan, D.W. Keith & J. Apt, *Cost Analysis of Stratospheric Albedo Modification Delivery Systems*, 7 ENVTL. RES. LETTERS 1, pg.# (2012).

45 *See* 2015 NRC REPORTS, *supra* note 2, at CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION.

46 Detlef P. van Vuuren et al., *A New Scenario for Climate Change Research: Scenario Matrix Architecture*, 122 CLIMATIC CHANGE 373 (2013); T.M.L. Wigley, *A Combined Mitigation/Geoengineering Approach to Climate Stabilization*, 314 SCI. 452 (2006).

47 *See* 2015 NRC REPORTS, *supra* note 2, at; Ben Kravitz et al., *Geoengineering: Whiter Skies?* 39 GEOPHYSICAL RES. LETTERS 1, pg.# (2012); Ben Kravitz et al., *Sulfuric Acid Deposition From Stratospheric Geoengineering with Sulfate Aerosols*, 114 J. GEOPHYSICAL RES. 1, pg.# (2009); Simone Tilmes et al., *The Sensitivity of Polar Ozone Depletion to Proposed Geoengineering Schemes*, 320 SCI. 1201, pg.# (2008).

rine ecosystems from ocean sequestration;[48] large quantities of solid waste and land-use disruption from enhanced weathering;[49] and induced seismicity or re-release of stored material from geological sequestration.[50]

These risks would be present even with ideally competent and prudent CE deployment. Other risks are not intrinsic to the methods, but depend on how they are used. Beneficial CE scenarios presume competent, multi-decade management of the technologies for societal benefit, a presumption with few historical precedents. If CE is instead used incompetently or malevolently, resultant harms could overwhelm benefits. In the extreme, CE could catastrophically disrupt global climate, worse than any plausible outcome of increased greenhouse gases.[51] More likely, and so of greater concern, are scenarios of less extreme misuse, particularly relying on CE too much. CE might divert efforts from essential emission cuts and adaptation.[52] Such excessive reliance might be especially likely if early development of CE weakens capacity to control its subsequent expansion, through political, economic, or perceptual mechanisms typically called "lock-in" or "slippery slope."[53] Moreover, if radiation methods were expanded for decades with no emission cuts, they could suppress several degrees of heating, which would be re-imposed within months, with severe impacts, if CE efforts stopped.[54]

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[48] *See generally* A.L. Strong et al., *Ocean Fertilization: Science, Policy, and Commerce*, 22 OCEANOGRAPHY 236 (2009).

[49] J. Hartmann et al., *Enhanced Chemical Weathering as a Geoengineering Strategy to Reduce Atmospheric Carbon Dioxide, Supply Nutrients, and Mitigate Ocean Acidification*, 51 REVIEWS OF GEOPHYSICS 113, pg.# (2013).

[50] J. Lee, M. Weingarten & S. Ge, *Induced Seismicity: The Potential Hazard From Shale Gas Development and CO_2 Geological Storage*, 20 GEOSCIENCES J. 137, pg.# (2016).

[51] *See generally* Paul F. Hoffman et al., *A Neoproterozoic Snowball Earth*, 281 SCI. 1342 (1998).

[52] *See, e.g.*, David Morrow, *Ethical Aspects of the Mitigation Obstruction Argument against Climate Engineering Research*, 372 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y, pg.# (2014); Adam Corner & Nick Pidgeon, *Geoengineering, Climate Change Skepticism, and the 'Moral Hazard' Argument*, 372 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y, pg.# (2014); B. Hale, *The World That Would Have Been: Moral Hazard Arguments Against Geoengineering*, *in* ENGINEERING THE CLIMATE: THE ETHICS OF SOLAR RADIATION MANAGEMENT pg.# (C.J. Preston ed., 2012). *But see* Lennart Bengtsson, Editorial Comment, *Geoengineering to Confine Climate Change: Is It at All Feasible?* 77 CLIMATIC CHANGE 229, 233 (2006).

[53] *See* ROSE CAIRNS, GEOENGINEERING: ISSUES OF PATH-DEPENDENCE AND SOCIO-TECHNICAL LOCK-IN __ (2013), *available at* http://geoengineering-governance-research.org/perch/resources/background-briefing.pdf.

[54] *See generally* A. Jones et al., *The Impact of Abrupt Suspension of Solar Radiation Management (Termination Effect) in Experiment G2 of the Geoengineering Model Intercomparison Project (GeoMIP)*, 118 J. GEOPHYSICAL RES. 9743 (2013).

CE may also represent a potent new source of international conflict. The large potential for disagreement over CE is already evident in the intensity of current debates. As climate impacts grow worse, these disagreements could generate severe international conflicts.[55] The most extreme conflict prospects would arise if advancing capabilities appeared to allow CE to control regional climates—a modern echo of Cold-War worries over hostile weather modification.[56] Other avenues for conflict arise from the relative ease and low cost of radiation methods and resultant prospects for unilateral use, for at least a dozen-odd world powers.[57]

These concerns pertain to potential large-scale CE for operational climate control, usually thought to lie decades in the future, but related controversies extend to near-term research. Many observers judge research urgently needed, to assess efficacy and risks of CE and support informed future decisions whether and how to use it.[58] Research may also be needed to detect and respond to unsanctioned use.[59] These arguments apply to laboratory and computer-model research, now proceeding at modest scale with little controversy.[60] They also apply to small-scale field studies, including active perturbations with *de minimis* direct environmental impact (typically smaller than a single long-distance flight or ship crossing)[61]—which are needed to test methods, validate models, and assess risks.[62]

Yet even small-scale research proposals have attracted opposition.[63] The most serious objections arise from "lock-in" hypotheses as stated

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[55] Philip Boyd, *Geopolitics of Geoengineering*, 2 NATURE GEOSCIENCE 812, pg.# (2009).

[56] ROBERT L. OLSON, WOODROW WILSON INT'L CTR. FOR SCHOLARS, GEOENGINEERING FOR DECISION MAKERS 16 (2011), *available at* http://www.wilsoncenter.org/sites/default/files/Geoengineering_for_Decision_Makers_0.pdf.

[57] *See* Daniel Bodansky, *The Who, What, and Wherefore of Geoengineering Governance*, 121 CLIMATIC CHANGE 539, 541, 547-48 (2013).

[58] *See supra* notes 4-5.

[59] *See* M. Granger MORGAN & K. RICKE, INT'L RISK GOVERNANCE COUNCIL [IRGC], COOLING THE EARTH THROUGH SOLAR RADIATION MANAGEMENT: THE NEED FOR RESEARCH AND AN APPROACH TO ITS GOVERNANCE 16 (2010); D.G. Victor, *On the regulation of geoengineering*, OXF REV ECON POLICY 24:2 (2008), at 334.

[60] *See* 2015 NRC REPORTS, *supra* note 2, at pg.#.

[61] Parson & Keith, *supra* note 4, at 1279.

[62] *See* BPC RPT., *supra* note 5, at 3, 12; Keith, Parson & Morgan, *supra* note 4, at 426; Jason J. Blackstock & Jane C. S. Long, *The Politics of Geoengineering*, 327 SCI. 527, 527 (2010).

[63] *See, e.g.*, *A Charter for Geoengineering*, *supra* note 9, at 415. *See generally* Malcolm J. Wright, Damon A. H. Teagle & Pamela M. Feetham, *A Quantitative Evaluation of the Public Response to Climate Engineering*, 4 NATURE CLIMATE CHANGE 106 (2014).

above.[64] A subtle form of this objection posits a general perverse relationship between ability to learn about a new technology and control it.[65] Applied to CE, this would mean interventions big enough to provide useful knowledge about capabilities and risks will create entrenched interests that obstruct meaningful control.[66] In principle, such loss of control could occur at various thresholds, such as the shift to outdoor research or to active perturbations, or the involvement of commercial or military interests[67] -- or even in the past, as when Crutzen's 2006 editorial prompted renewed debate of CE.[68]

Other objections argue that CE field research cannot be meaningfully distinguished from deployment,[69] or that it risks political backlash against needed climate-science research.[70] Finally, some commentators reject CE on principled grounds, arguing the endeavor is hubristic, improperly manipulates nature for human purposes, is unjust, or replicates the reductionist, technology-centered thinking that caused the climate-change problem.[71]

The current range of debate extends from some who would prohibit all CE, including research, to others who would allow various forms and scales of research to proceed, subject to national or international regulatory re-

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[64] *See supra* note 53.

[65] *See generally* DAVID COLLINGRIDGE, THE SOCIAL CONTROL OF TECHNOLOGY (1980).

[66] *See* Stephen H. Schneider, *Geoengineering: Could We or Should We Make it Work?* 336 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y A 3843, 3856-57 (2008).

[67] *See* Richard Elliot Benedick, *Considerations on Governance for Climate Remediation Technologies: Lessons from the "Ozone Hole,"* 4 STAN. J.L. SCI. & POL'Y 6. 7 (2011); Blackstock & Long, *supra* note 63, at 527. *Cf.* ELI KINTISCH, HACK THE PLANET 8 (2010).

[68] *See* Mark G. Lawrence, *The Geoengineering Dilemma: To Speak or Not to Speak*, Editorial Comment, 77 CLIMATIC CHANGE 245, 245 (2006).

[69] *See, e.g.*, Alan Robock et al., *A Test for Geoengineering?* 327 SCI. 530, 530 (2010); Jane C. S. Long, *A Prognosis, and Perhaps a Plan, for Geoengineering Governance*, 7 CARBON & CLIMATE L. REV. 177, 179 (2013); ETC GROUP, GEOPIRACY: THE CASE AGAINST GEOENGINEERING __ (2010), *available at* www.etcgroup.org/content/geopiracy-case-against-geoengineering [hereinafter ETC GROUP, GEOPIRACY].

[70] Stefan Schafer et al., *Field Tests of Solar Climate Engineering*, Opinion & Comment, 3 NATURE CLIMATE CHANGE 766, 766 (2013); Joshua B. Horton, *Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International Cooperation*, 4 STAN. J.L. SCI. & POL'Y 56, 58 (2011).

[71] *See, e.g.*, MIKE HULME, CAN SCIENCE FIX CLIMATE CHANGE?: A CASE AGAINST CLIMATE ENGINEERING pg.# (2014); David R. Morrow, Robert E. Kopp & Michael Oppenheimer, *Toward Ethical Norms and Institutions for Climate Engineering Research*, 4 ENVTL. RES. LETTERS 1, pg.# (2009); ETC GROUP, GEOPIRACY, *supra* note 70, at 39.

quirements ranging from very light to highly restrictive.[72]

B. Current Status of Research and Governance

There is no operational-scale CE underway or now proposed anywhere in the world. While weather-modification programs operate in a few countries,[73] current CE proposals are limited to small-scale research. The governments of the United States, European Union, United Kingdom, and Germany have provided modest funding, mostly for modeling and laboratory research.[74]

The boundaries of CDR research are not clearly defined, because much study of carbon dynamics in forests, soils, and the ocean is directly relevant.[75] Two small field trials of ocean CO_2 injection were stopped by public opposition.[76] Several experiments have examined ocean carbon sequestration by adding nutrients to fertilize plankton growth.[77] Like ocean CO_2 disposal, these experiments raised substantial controversy.[78] A few researchers and firms are developing methods to remove CO_2 directly from the atmosphere, but none has progressed beyond small demonstrations.[79]

Research on radiation methods has mostly consisted of computer model-

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[72] *See* 2015 NRC REPORTS, *supra* note 2, at pg.#; Andy Parker, *Governing Solar Geoengineering Research as it Leaves the Laboratory*, 372 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y, pg.# (2014).

[73] *See* Long, *supra* note 70, at 183.

[74] *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFF., A COORDINATED STRATEGY COULD FOCUS FEDERAL GEOENGINEERING RESEARCH AND INFORM GOVERNANCE EFFORTS, GAO-10-903 app. IV (2010), *available at* http://www.gao.gov/new.items/d10903.pdf.

[75] Philippe Ciais et al., *Carbon and Other Biogeochemical Cycles*, *in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS pg.# (T.F. Stocker et al. eds., 2013).

[76] *See* M.A. de Figueiredo, D.M. Reiner, H.J. Herzog, *Ocean Carbon Sequestration: A Case Study in Public and Institutional Perceptions*, 1 PROC. SIXTH INT'L CONF. ON GREENHOUSE GAS CONTROL TECHNOLOGIES 799, pg.# (2003); J. P. Barry et al., *Effects of Direct Ocean CO_2 Injection on Deep-Sea Meiofauna*, 60 J. OCEANOGRAPHY 759, pg.# (2004); Peter G. Brewer et al., *Direct Experiments on the Ocean Disposal of Fossil CO_2*, 284 SCI 943, pg.# (1999).

[77] *See* P.W. Boyd et al., *Mesoscale Iron Enrichment Experiments 1993-2005: Synthesis and Future Directions*, 315 SCI. 612, pg.# (2007); Ken O. Buesseler et al., *Ocean Iron Fertilization—Moving Forward in a Sea of Uncertainty*, 319 SCI. 161 (2008).

[78] *See* Phillip Williamson et al., *Ocean Fertilization for Geoengineering: A Review of Effectiveness, Environmental Impacts and Emerging Governance*, 90 PROCESS SAFETY & ENVTL. PROTECTION 475, pg.# (2012); Jeff Tollefson, *Ocean Fertilization Project Off Canada Sparks Furor*, 490 NATURE, pg.# (2012).

[79] *See* ROBERT SOCOLOW ET AL., AM. PHYSICAL SOC'Y PANEL ON PUB. AFFAIRS, DIRECT AIR CAPTURE OF CO2 WITH CHEMICALS pg.# (2011); Eli Kintisch, *Can Sucking CO_2 Out of the Atmosphere Really Work?* MIT TECH. REV. (Oct. 7, 2014).

ing, lab-bench studies, and passive observation of perturbations such as volcanos or ship and aircraft tracks, funded by existing research programs and some private philanthropy.[80] A planned U.K. experiment spraying water to test aerosol disbursement was stopped over concerns about inadequate public consultation and conflicts of interest.[81] One small tropospheric aerosol-injection study has been conducted in Russia[82] and one in the United States[83]—both "dual-use" studies that informed scientific questions as well as potential CE. Several research groups have proposed field experiments on radiation methods, none funded as of 2016.[84]

Even more than CE research, CE governance is in its infancy. There is virtually none at the international level, even under the most seemingly relevant treaties.[85] Parties to two international treaties—the Convention on Biological Diversity[86] and the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)[87]— adopted resolutions expressing concerns about CE and urging nations to exercise oversight, but these are nonbinding.[88] In 2013, parties to

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[80] 2015 NRC REPORTS, *supra* note 2, at CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH; Ben Kravitz et al., *An Overview of the Geoengineering Model Intercomparison Project (GeoMIP)*, 118 J. GEOPHYSICAL RES. 13103, pg.# (2013).

[81] N.F. Pidgeon et al., *Deliberating Stratospheric Aerosols for Climate Geoengineering and the SPICE Project*, 3 NATURE CLIMATE CHANGE 451, pg.# (2013).

[82] *See* Yu A. Izrael et al., *Field Studies of a Geo-Engineering Method of Maintaining a Modern Climate with Aerosol Particles*, 34 RUSSIAN METEOROLOGY & HYDROLOGY 635, pg.# (2009).

[83] *See* Lynn M. Russell et al., *Eastern Pacific Emitted Aerosol Cloud Experiment*, 94 BULL. AM. METEOROLOGICAL SOC'Y 709, pg.# (2013).

[84] *See, e.g.*, John Latham, Philip J. Rasch & Brian Launder, *Climate Engineering: Exploring Nuances and Consequences of Deliberately Altering the Earth's Energy Budget*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A, pg.# (2014); John A. Dykema et al., *Stratospheric Controlled Perturbation Experiment: A Small-Scale Experiment to Improve Understanding of the Risks of Solar Geoengineering*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A, pg.# (2014).

[85] Edward A. Parson & Lia N. Ernst, *International Governance of Climate* Engineering, 14 THEORETICAL INQUIRIES IN LAW 307, pg.# (2013); SHEPHERD ET AL., *supra* note 2, at 40; *but cf.* Ralph Bodle, *Climate Law and Geoengineering*, *in* CLIMATE CHANGE AND THE LAW 449 (Erkki J. Hollo et al. eds., (2013).

[86] Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79; 31 I.L.M. 818.

[87] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Dec. 29, 1972, 26 U.S.T. 2403, 1046 U.N.T.S. 120, 11 I.L.M. 1294 [hereinafter London Convention].

[88] Dec. X/33 on Biodiversity and Climate Change, *in* [United Nations Environment Programme] UNEP, Report of the Conference of the Parties to the Convention on Biological Diversity at Its Tenth Meeting ¶ 8, U.N. Doc. UNEP/CBD/COP/10/27 (Oct. 29, 2010); Res. LC-LP.1 on the Regulation of Ocean Fertilization, 13th meeting of the Contracting Parties to the London Convention, 8, UN Doc. LC/30/16/Annex 6 (Oct.

the 1996 Protocol to the London Convention[89] adopted a legally binding amendment that prohibits "marine geoengineering" activities, with an exception for "legitimate scientific research" on ocean fertilization authorized by national permit.[90] The practical impact of this decision is limited, however, by growing evidence that ocean fertilization is not a viable CE approach and by the fact that neither the United States nor Russia is party to the Protocol. There has been no international decision similarly binding on any radiation method. Thus, with the exception of ocean fertilization, any country is free to conduct CE over its own territory, that of other consenting states, or the high seas, subject only to customary-law principles regarding, for example, transboundary harm, environmental impact assessment, and public participation in decision-making.[91] Lack of international governance does not, however, mean lack of any governance. CE activities may trigger domestic laws,[92] and all research is subject to scientific self-governance and the conditions of funders, who exercise some control over risky or controversial areas of research.[93]

In sum, CE might be valuable, even essential, to limit severe climate-change risks. It might also be dangerous, due to direct environmental effects or potential for misuse. Research might ease this tension, but generalized worries about CE have slowed research. Many commentators note the need for governance, but uncertainty about the nature and severity of risks implies uncertainty about governance needs. Research that might inform governance is not being done, and may be stifled by premature calls for excessively burdensome restrictions and worries about political backlash.[94] In

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31, 2008); Res. LC-LP.2(2010), by the Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention) and to the 1996 Protocol thereto (London Protocol).

[89] 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other matter, Nov. 7, 1996, 36 I.L.M. 7 [hereinafter London Protocol].

[90] Res. LP.4(8) on the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities (Oct. 18, 2013), Rep. of the 35th Consultative Meeting and 8th Meeting of Contracting Parties, UN Doc. LC 35/15 (Oct. 21, 2013).

[91] Parson & Ernst, *supra* note 86, at 322; Catherine Redgwell, *Geoengineering the Climate: Technological Solutions to Mitigation Failure or Continuing Carbon Addition?* 2 CARBON & CLIMATE L. REV. 178 (2011). S*ee generally* Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 MICH. J. INT'L L. 309 (2013).

[92] *See generally* Tracy D. Hester, *Remaking the World to Save It: Applying U.S. Environmental Laws to Climate Engineering Projects*, 38 ECOL. L.Q. 851 (2011).

[93] *See generally* Gary E. Marchant & Lynda L. Pope, *The Problems with Forbidding Science*, 15 SCI. & ENGINEERING ETHICS 375 (2009).

[94] *See, e.g.*, Jane C.S. Long et al., Comment, *Policy: Start Research on Climate Engineering*, 518 NATURE 29 (2015).

the context of this stalled debate, multiple commentators have proposed that some form of moratorium on CE might help loosen the current deadlock and help develop effective and legitimate governance.[95] In the next section, we introduce the general concept of a moratorium and review proposals for CE-related moratoria.

II. MORATORIA

Despite the importance of moratoria and the extensive historical experience with them, there is a surprising dearth of analytic treatment of moratoria in the legal and social-science scholarly literature. The concept of a moratorium suffers from substantial definitional and analytic confusion, both in scholarly publications and as used in practice. Most scholarly work is limited to descriptive accounts of a single case, and no prior study draws on more than two. Of the three works that attempt to draw inferences about origins, structure, or effects of moratoria, two propose limited generalizations based on just two cases,[96] while the third presents various conclusory claims about moratoria in international law based on a brief and perfunctory empirical foundation.[97] In view of these limitations, in Parts III-IV we aim to develop a general analytic framework to examine moratorium purposes, conditions, and outcomes broadly across issues, based on our larger set of cases. We use this framework to inform our analysis of a potential CE moratorium, and also aim for it to make a broader contribution to the understanding of moratoria and their uses in diverse contexts. This section considers the meaning of a moratorium and the principal characteristics that define one. It then summarizes current proposals for CE-related moratoria and situates them relative to these characteristics.

A. Defining Moratoria

A moratorium is a temporary or provisional prohibition of some specified activity.[98] The term originates in the *preaescripta moratoria* of Roman

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[95] *See, e.g.*, Redgwell, *supra* note 91, at 183, 189; Bodansky, *supra* note 58; Parker, *supra* note 73, at __.

[96] Sarah Lieberman, Tim Gray & A. J. R. Groom, *Moratoria in International Politics: A Comparative Analysis of the Moratoria on Genetically Modified Products and Commercial Whaling*, 14 BRITISH J. POLITICS & INT'L REL. 518, 518 (2012); ROBERT MULLAN COOK-DEEGAN, NAT'L BIOETHICS ADVISORY COMM'N, CLONING HUMAN BEINGS: DO RESEARCH MORATORIA WORK? 4 (1997).

[97] W. Yin, *Moratorium in International Law*, 11 Chinese J. Int'l L. 321, pg.# (2012).

[98] *C.f.* BLACK'S LAW DICTIONARY (9th ed. 2009); .Lieberman, Gray, & Groom, *supra* note 96; COOK-DEEGAN, *supra* note 96; W. Yin, *Moratorium in International Law*, 11 Chinese J. Int'l L. 321, pg.# (2012).

law, "a deferment of payment granted by an imperial edict."[99] Over time, the term broadened to encompass general suspensions of any activity, adopted voluntarily or under domestic or international law.[100] The essential characteristic of a moratorium is that the suspension has a time-limited or provisional character.[101] Whether or not conditions for terminating a moratorium are explicitly stated, some such limitation is essential to the concept. A moratorium is intermediate between consent and prohibition, and may be followed by prohibition of the suspended activity, resumption, or resumption subject to specified limits or controls.

To define and implement a moratorium requires specifying several characteristics, three of which are most basic: the moratorium's scope, its associated actors, and its termination conditions. A moratorium's scope defines what activities fall under it. Its associated actors define both who adopts it and who is bound by it. The identity and roles of associated actors are closely related to the structure of obligations a moratorium creates. For example, those adopting a moratorium and bound by it can be the same, as when a group of actors collectively adopt a moratorium to bind themselves. Alternatively, those adopting a moratorium may aim to restrain other actors' conduct. This distinction often corresponds to a moratorium's voluntary or binding character, in that a group mutually adopting a moratorium will often have only normative suasion available for enforcement, while an outside actor may command additional forms of authority, control over resources and incentives, or legally binding controls.

A moratorium's termination conditions describe when, or under what conditions, it will end. Termination conditions can be defined by duration ("after 10 years"), external conditions ("if observed increase in global-average temperature exceeds 2.5 degrees Celsius"), procedural decision rules ("if a majority of participants so decide at their annual meeting"), or some combination. However stated, termination conditions may function as guidelines or shared expectations rather than binding requirements, depending on the binding or voluntary character of the moratorium itself and the future actors who will act upon the termination conditions at the time. Decisions to adopt a moratorium often include additional provisions—e.g., committing parties to do certain things while the moratorium is in effect, or establishing processes to manage the moratorium or conduct related activities. As we will discuss, these other activities may affect whether a moratorium's aims are achieved, but we regard them as distinct from the moratori-

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[99] Alexander Riedel, *Moratorium, in* ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW, vol. 3, 464 (R. Bernhardt ed., 1992)).
[100] Yin, *supra* note 97, at 321-24; COOK-DEEGAN, *supra* note 96, at 518.
[101] Yin, *supra* note 97, at 333.

um, not intrinsic to its definition or specification.

B. Proposals for a Climate Engineering Moratorium

We have identified eighteen CE moratorium proposals, advanced over the past several years by the following proponents: Hubert and Reichwein,[102] the Parties to the Convention on Biological Diversity;[103] the editors of Nature;[104] the Kiel Earth Institute;[105] the Woodrow Wilson International Center;[106] Blackstock and Long;[107] Cicerone;[108] Davis;[109] Markus and Ginsky;[110] Parson and Keith;[111] Morgan, Nordhaus, and Gottlieb;[112] Schafer et al.;[113] Robock;[114] two separate groups of participants at the 2014 Climate Engineering Conference;[115] former UK Chief Scientific Advisor Sir David King;[116] Greenpeace;[117] and the ETC Group.[118] Some proposals are

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[102] Anna-Maria Hubert & David Reichwein, *An Exploration of a Code of Conduct for Responsible Scientific Research Involving Geoengineering* 50 (Inst. Advanced Sustainability Studies Working Paper, 2015).

[103] Dec. X/33 on Biodiversity and Climate Change, *supra* note 89.

[104] *A Charter for Geoengineering*, *supra* note 9, at 415.

[105] WILFRIED RICKELS ET AL., KIEL EARTH INST., LARGE-SCALE INTENTIONAL INTERVENTIONS INTO THE CLIMATE SYSTEM? ASSESSING THE CLIMATE ENGINEERING DEBATE 118 (2011).

[106] OLSON, *supra* note 57, at 44.

[107] Blackstock & Long, *supra* note 63, at 527.

[108] Cicerone, *supra* note 26, at 224-25.

[109] William Daniel Davis, *What Does "Green" Mean? Anthropogenic Climate Change, Geoengineering, and International Environmental Law*, 43 GA. L. REV. 901, 945 (2009).

[110] Till Markus & Harald Ginsky, *Regulating Climate Engineering: Paradigmatic Aspects of the Regulation of Ocean Fertilization*, 4 CARBON & CLIMATE L. REV. 477, 484 (2011).

[111] Parson & Keith, *supra* note 61, at 1278.

[112] Morgan, Nordhaus & Gottlieb, *supra* note 4.

[113] Schafer et al., *supra* note 71, at 766.

[114] Alan Robock, *Is Geoengineering Research Ethical?*, 4 PEACE & SECURITY 226, 228 (2012).

[115] DRAFT – PROPOSED BERLIN DECLARATION (2014), *available at* http://www.ce-conference.org/sites/default/files/wysiwyg/files/draft_-_proposed_berlin_declaration.pdf [hereinafter BERLIN DECLARATION]; A FRAMEWORK FOR MORE DEMOCRATIC GOVERNANCE OF CLIMATE ENGINEERING (2014), *available at* http://www.ce-conference.org/sites/default/files/wysiwyg/files/draft_scandic_principles.pdf [hereinafter SCANDIC PRINCIPLES].

[116] SCI. & TECH. COMM., U.K. HOUSE OF COMMONS, THE REGULATION OF GEOENGINEERING, 5TH RPT. SESSION 2009-10, 37 (2010), *available at* http://www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/221.pdf.

[117] GREENPEACE, GREENPEACE'S KEY PRIORITIES FOR CBD COP10 3 (2010), *available at* http://www.greenpeace.org/international/en/publications/reports/CBD/.

highly provisional, expressed only in draft documents or oral testimony. Some are incomplete or ambiguous regarding proposed terms, or stated so vaguely as to allow disagreement whether it actually calls for a moratorium.[119] Despite these ambiguities, we outline here, to the extent possible, where these proposals stand on the characteristics outlined above, scope, actors, and termination conditions.

In their scope, all these proposals include at least large-scale operational deployment. Some distinguish interventions by type or method,[120] with more targeting radiation methods than CDR.[121] Some distinguish research from operational interventions by quantitative measures of scale,[122] or by less explicit measures of intensity or impact.[123] Others distinguish research interventions from those that aim to develop or inform an operational capability, but offer little guidance how to draw such purpose-based distinctions in practice.[124] The strictest proposals suspend field experiments of even the smallest scale.[125] Some proposals, while vague, can be read to cover even computer-model and laboratory studies, although this would also require drawing difficult to enforce boundaries based on the purpose of a research project.[126]

In terms of actors, proposals include examples of both mutual adoption

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[118] ETC GROUP, GEOPIRACY, *supra* note 70, at 2, 40; DIANA BRONSON, PAT MOONEY & KATHY JO WETTER, ETC GROUP, RETOOLING THE PLANET? CLIMATE CHAOS IN THE GEOENGINEERING AGE 37 (2009), *available at* http://www.etcgroup.org/sites/www.etcgroup.org/files/publication/pdf_file/Retooling%20the%20Planet%201.2.pdf.

[119] In some cases, we identify a proposal as calling for a moratorium as defined above (i.e., it calls for suspending some activity for a specified time or until certain conditions are met) even when it is not explicitly identified as such, or some of its authors state it does not call for a moratorium. E.g., one author of the BERLIN DECLARATION, *supra* note 116, states that it did not represent a moratorium proposal. Email communication with Steve Rayner (Nov. 2, 2014), on file with authors.

[120] *See, e.g.*, Markus & Ginsky, *supra* note 111, at 484.

[121] *See, e.g.*, Parson & Keith, *supra* note 61, at 1278; Robock, *supra* note 114, at 241; Schafer et al., *supra* note 71, at 766; THE REGULATION OF GEOENGINEERING, *supra* note 117, at 37.

[122] Parson & Keith, *supra* note 61, at 1278-79.

[123] *See, e.g.*, OLSON, *supra* note 57, at 44; Cicerone, *supra* note 26, at 225; RICKELS ET AL., *supra* note 106, at 118; Morgan, Nordhaus & Gottlieb, *supra* note 4, at 41; Dec. X/33 on Biodiversity and Climate Change, *supra* note 89.

[124] *See, e.g.*, Lawrence, *supra* note 69, at 246; Davis, *supra* note 110, at 945; Hubert & Reichwein, *supra* note 103, at 50.

[125] *See, e.g.*, Schafer et al., *supra* note 71, at 766; Blackstock & Long, *supra* note 63, at 527; BRONSON, MOONEY, & WETTER, *supra* note 119, at 37; ETC GROUP, GEOPIRACY, *supra* note 70, at 2, 40.

[126] *See* Hubert & Reichwein, *supra* note 103, at 50; GREENPEACE, *supra* note 118, at 3.

by a group and imposition by an outside authority. Some call on scientists to voluntarily refrain from specified CE-related activities, while others call on governments to limit activities through funding restrictions or regulation.[127] Proposed termination conditions include building public confidence and knowledge about risks,[128] agreement on governance for CE research[129] or for all CE,[130] or adequate limitations on global greenhouse-gas emissions.[131] Although most proposals do not include explicit statements of their purpose or arguments how the moratorium would advance that purpose, termination conditions give some insight into intended purpose. One proposal is so strict, or so ambiguous, in its termination conditions that it lies on the boundary between a moratorium and a full prohibition—even using the terms "moratorium" and "ban" interchangeably.[132]

III. EXPERIENCE WITH MORATORIA IN OTHER DOMAINS

Although CE and the legal and policy challenges it poses are novel, the use of moratoria as tools to manage contentious or risky issues is not. Historical experience with moratoria is extensive, and diverse in decision contexts, moratorium characteristics, aims, and outcomes. In view of the clear relevance of this historical experience for assessing proposed moratoria on CE, this Part reviews this historical experience in search of relevant insights.

In response to the limitations of the prior literature on moratoria, we develop an analytic framework to understand moratorium purposes, conditions, and outcomes, based on the larger set of cases we consider. The definitional confusion that characterizes prior commentary on moratoria also poses challenges for our selection of cases, as the set of acts called "morato-

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[127] *See, e.g.*, Parson & Keith, *supra* note 61; Schafer et al., *supra* note 71, at 766; Davis, *supra* note 110, at 945; RICKELS ET AL., *supra* note 106, at 117-18; Cicerone, *supra* note 26, at 224; BERLIN DECLARATION, *supra* note 116.

[128] *See, e.g.*, Schafer et al., *supra* note 71, at 766; Parson & Keith, *supra* note 4, at __; Hubert & Reichwein, *supra* note 103, at 50.

[129] *See, e.g.*, OLSON, *supra* note 57, at 39; Cicerone, *supra* note 26, at 224; *A Charter for Geoengineering*, *supra* note 9, at 415.

[130] *See, e.g.*, BRONSON, MOONEY, & WETTER, *supra* note 119, at 37; Schafer et al., *supra* note 71, at 766; Hubert & Reichwein, *supra* note 103, at 50.

[131] *See* Cicerone, *supra* note 26, at 224.

[132] E.g., the ETC Group has described its overall goal as "strict prohibition of any deployment of geoengineering technologies *at least* until proper governance mechanisms are in place" (BRONSON, MOONEY, & WETTER, *supra* note 119, at 39 (emphasis added)), and "a ban on all testing or deployment of geoengineering technologies," (*Mission & Current Focus*, ETC GROUP, http://www.etcgroup.org/mission (last visited May 8, 2014)).

ria" by policy actors and scholars blurs in both directions, toward prohibition and regulation. We address this by considering only cases that clearly suspended some well-defined set of activities (rather than regulating or categorically prohibiting them), for which the suspension was clearly intended by at least some proponents to be conditional or time-limited. In addition, for practical reasons, we limit our scope to cases where moratoria were enacted either formally or *de facto*, rather than merely proposed;[133] that are recent (since roughly mid-twentieth century); that attracted significant US or international debate; and that are addressed in an adequate secondary literature.

This selection yields twelve cases in two broad subject-matter areas: international diplomacy, and controversial scientific research and technology. Parts III-A and III-B provide brief reviews of the cases in each area, considering the context in which a moratorium was proposed, its scope and form, the aims of its proponents, and evidence of its effects. Part IV re-examines the cases from an analytic perspective, first grouping them in a taxonomy based on the moratorium's intended or claimed purposes, which is more analytically useful than the subject-matter grouping. This represents the first attempt to develop a general framework for analyzing moratoria, which we conjecture is of broad generalizability and use in diverse cases of moratoria. In Part V, we apply this framework to the design, uses, and potential benefits of a moratorium for CE. Part VI offers preliminary conclusions, on a moratorium for CE and on potential further development of our analytic scheme and its application to other issues where moratoria are proposed.

A. Moratoria in International Diplomacy

We review seven cases of moratoria as tools to manage conflicts in international diplomacy. The cases are diverse in issue-area, covering fields of natural-resource allocation and management, international security, and trade. They are also diverse in structure, with some best understood as distributive conflicts, others as collective-action problems or principled conflicts.[134] In some cases, a moratorium was a negotiation tool to help states reach a mutually preferred decision. In others, a moratorium represented a

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[133] We thus do not consider proposals for a universal moratorium on the death penalty (See, e.g., G.A. Res. 65/206, U.N. Doc. A/65/206, Dec. 21, 2010); or on human germ-line modification using the CRISPR/Cas9 technology (See, e.g., David Baltimore et al., *A Prudent Path Forward for Genomic Engineering and Germline Gene Modification*, 348 SCI. 36, pg.# (2015).

[134] For a review of these alternative structures of interests, *see generally* THOMAS C. SCHELLING, STRATEGY OF CONFLICT (1960); HOWARD RAIFFA, THE ART AND SCIENCE OF NEGOTIATION (1982).

shift in collective practice, over which states persistently disagreed.

1. Antarctic Territorial Claims

A moratorium on sovereign territorial claims in Antarctica has served for decades as a foundation of the continent's international governance system.[135] The system developed over a decade, following the emergence of contending Antarctic claims as a major source of international tension in the 1940s. Seven nations made territorial claims—the United Kingdom, New Zealand, France, Norway, Australia, Chile, and Argentina—with overlaps between those of Argentina, Chile, and the United Kingdom.[136] The United States and Soviet Union neither made claims nor recognized those of others, but regarded Antarctica as geopolitically important and maintained a basis of claim through exploration and scientific research.[137] The United States had considered advancing a territorial claim, but on balance judged its interests in free access and limiting Soviet reach to outweigh the benefits of a claim.[138]

Growing conflict over claims and broader Cold-War tensions moved several states to seek international resolution. In 1948, the United States proposed that Antarctica be administered under either of two arrangements: a U.N. trusteeship, or a condominium that would merge all claims and establish a governing commission.[139] In either form, the United States would advance its own claim to join the seven prior claimants in governing arrangements. When only two nations supported this proposal, Chile instead proposed a *modus vivendi* arrangement, which would freeze claims and objections for five to ten years.[140] By separating Antarctic activities from claims, the *modus vivendi* would let states freely conduct research on the continent, and would remove incentives to mount new bases or expeditions merely to strengthen or contest claims.[141] The United States found the pro-

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[135] *See generally* GOVERNING THE ANTARCTIC: THE EFFECTIVENESS AND LEGITIMACY OF THE ANTARCTIC TREATY SYSTEM (O. S. Stokke & D. Vidas eds., 1996).

[136] *See Territories Claimed by Sovereign States in the Antarctic*, 10 POLAR REC. 163, pg.# (1960).

[137] *See* Boleslaw A. Boczek, *The Soviet Union and the Antarctic Regime*, 78 AM. J. INT'L L. 834, 840-46 (1984); U.S. ANTARCTIC PROGRAM EXTERNAL PANEL, THE UNITED STATES IN ANTARCTICA 17-19, 21 (1997).

[138] *See generally* Jason Kendall Moore, *A 'Sort' of Self-Denial: United States Policy Toward the Antarctic, 1950-59*, 37 POLAR REC. 13 (2001).

[139] *See* U.S. DEP'T OF STATE, FOREIGN RELATIONS OF THE UNITED STATES 1948, vol. I, 977 (1948).

[140] Rip Bulkeley, *Political Origins of the Antarctic Treaty System*, 46 POLAR REC. 9, 10 (2010).

[141] *See* U.S. DEP'T OF STATE, *supra* note 141, at 1009.

posal attractive, as it offered advantages similar to its prior stance of neither making nor recognizing claims,[142] and began working with Chile on a modified proposal.[143]

The initiative stalled for several years as parties were distracted by other conflicts,[144] but interest revived during planning for the International Geophysical Year (IGY), a cooperative 1957-58 scientific project by the seven claimants plus the United States, Soviet Union, and three other states.[145] At the first IGY planning conference, states adopted a "Gentlemen's Agreement" similar to the prior *modus vivendi* proposals, stating that IGY activities "do not modify the existing status of the Antarctic regarding the relations of the participating countries."[146] The IGY's success showed the value of Antarctic scientific cooperation, the need to resolve territorial conflicts, and the practicality of a *modus vivendi* approach.[147]

Based on this experience, states began negotiating a treaty on Antarctic governance shortly after IGY. Although positions were initially far apart on territorial claims,[148] parties agreed to a subtly crafted moratorium provision that sharpened the approach of the *modus vivendi* and Gentleman's Agreement.[149] Crucially, the moratorium does nothing to claims or rights at the time of treaty adoption: claimants retain their claims; non-claimants retain any basis they had for unasserted claims; and all states retain rights to recognize or reject others' claims. Rather, the moratorium applies only to new or enlarged claims, and to bases for claims based on new activities, so long as the Treaty is in force. The moratorium thus removes incentives for activities to bolster claims. These terms, together with provisions for free scientific access and international decision-making, also weaken the force of prior claims in practice, although they remain formally in effect.

The claims moratorium has been crucial to the maturation of Antarctic governance over the subsequent fifty years. Scientific research has flourished on the continent, and parties meet annually to discuss issues such as

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[142] Bulkeley, *supra* note 142, at 10.

[143] U.S. DEP'T OF STATE, FOREIGN RELATIONS OF THE UNITED STATES 1949, vol. I, pp.800-02, 807-09 (1949).

[144] Bulkeley, *supra* note 142, at 10.

[145] *See generally* Moore, *supra* note 140.

[146] Gillian Triggs, *The Antarctic Treaty System: A Model of Legal Creativity and Cooperation*, *in* SCIENCE DIPLOMACY: ANTARCTICA, SCIENCE, AND THE GOVERNANCE OF INTERNATIONAL SPACES 39, 42 (Paul Arthur Berkman et al. eds., 2011); M.J. PETERSON, MANAGING THE FROZEN SOUTH 39 (1988).

[147] Bulkeley, *supra* note 142, at 10.

[148] *See* PETERSON, *supra* note 148, at 40; KLAUS DODDS, PINK ICE: BRITAIN AND THE SOUTH ATLANTIC EMPIRE ch. 5 (2002).

[149] Antarctic Treaty art. V, Dec. 1, 1959, 12 U.S.T. 794, 402 U.N.T.S. 71.

research, historical preservation, tourism, and environmental protection.[150] Cooperation facilitated by the moratorium also allowed parties to execute several related agreements, which make up the Antarctic Treaty System.[151]

2. Antarctic Mineral Activity

Although Antarctica's mineral potential remains largely unexplored, preliminary research suggests the continent may be rich in fossil fuels, precious metals, and other resources.[152] Negotiators of the 1959 Treaty judged mineral issues to be controversial and premature, so did not address them.[153] Commercial interest in resources rose in the 1970s, spurred by technological advances and new discoveries, but firms were reluctant to invest without a legal regime in place.[154] In 1976, Antarctic parties agreed to negotiate a treaty on energy and mineral activities, and established a voluntary moratorium on exploration and exploitation in the interim.[155]

After ten years negotiation, the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) was unanimously adopted by parties in 1988.[156] CRAMRA would allow mineral projects, subject to rigorous environmental assessment, consensus that proposed projects would have no significant adverse environmental effects, and exclusion of designated protected areas.[157] During the decade of negotiations, however, the international environmental movement had grown strong.[158] A broad coalition of environmental NGOs campaigned against CRAMRA, arguing that Antarctica should be made a "world park" with mining prohibited.[159] This

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[150] *See The Antarctic Treaty Explained*, BRITISH ANTARCTIC SURVEY, http://www.antarctica.ac.uk/about_antarctica/geopolitical/treaty/explained.php (last visited May 22, 2014).

[151] *See generally Essential Documents of the Antarctic Treaty System*, SECRETARIAT OF THE ANTARCTIC TREATY, http://www.ats.aq/e/ats_keydocs.htm (last visited May 22, 2014).

[152] *See, e.g.*, H. COMM. ON SCI. & TECH., 94TH CONG., POLAR ENERGY RESOURCES POTENTIAL (Comm. Print 1976).

[153] Brian Roberts, *International Co-operation for Antarctic Development: The Test for the Antarctic Treaty*, 19 POLAR REC. 107, 111 (1978).

[154] U.S. CONGRESS, OFF. TECH. ASSESSMENT, POLAR PROSPECTS: A MINERALS TREATY FOR ANTARCTICA 37 (1989).

[155] Christopher C. Joyner, *The Antarctic Minerals Negotiating Process*, 81 AM. J. INTL. L. 888, 890-91 (1987). *See* Recommendation IX-1, para. 8, Ninth Antarctic Treaty Consultative Party Meeting, London (1977).

[156] The Convention for the Regulation of Antarctic Mineral Resource Activities, June 2, 1988, 27 I.L.M. 859 [hereinafter CRAMRA].

[157] *Id. at* arts. 4, 18, 21-22, 41.

[158] *See* CHRISTOPHER C. JOYNER, GOVERNING THE FROZEN COMMONS: THE ANTARCTIC REGIME AND ENVIRONMENTAL PROTECTION 38, 50, 193-94, 245 (1998).

[159] F.M. AUBURN, ANTARCTIC LAW AND POLITICS 124, 259 (1982). *See generally* J.M.

group achieved two significant victories in 1989: the U.N. General Assembly passed a resolution supporting the world park proposal;[160] and more consequentially, Australia and France announced they would not ratify.[161] Because CRAMRA required ratification by all original Antarctic Treaty parties, this meant the treaty could not enter into force.[162]

After CRAMRA's defeat, international opposition to Antarctic mining remained strong while treaty supporters resisted efforts to establish a permanent ban.[163] In the United States, Congress barred U.S. firms from Antarctic mineral activity and endorsed a permanent ban,[164] even while the Executive Branch pressed other parties to preserve the option of future development.[165] In 1991, parties adopted the Madrid Protocol on Environmental Protection, which designated Antarctica a "natural reserve, devoted to peace and science"[166] and imposed a fifty-year moratorium on "[a]ny activity relating to mineral resources, other than scientific research."[167] After fifty years, parties may hold a review conference, at which a majority may adopt CRAMRA or negotiate a new mineral regime.[168] At U.S. behest, the moratorium also includes a "walk-out" clause: if an amendment to establish a mineral regime is proposed but fails to enter into force within three years, any party may then withdraw from the Protocol and start mining after two more years.[169] This provision lets a state escape the moratorium by proposing a mineral regime as an amendment. Other states would have to either adopt the regime, or allow the proposing state to withdraw and start mining.

Environmental groups would have preferred a complete ban, but still regarded the moratorium as a victory.[170] Even weakened by the walk-out clause, the moratorium creates a presumption against mining and procedur-

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Spectar, *Saving the Ice Princess: NGOs, Antarctica & International Law in the New Millennium*, 23 SUFFOLK TRANSNAT'L L. REV. 57 (1999).

[160] U.N. Doc. A/C.1/44 L.59, U.N. GAOR, 44th session (1989).

[161] Malcolm W. Browne, *France and Australia Kill Pact on Limited Antarctic Mining and Oil Drilling*, N.Y. TIMES, Sept. 25, 1989.

[162] CRAMRA, *supra* note 159, at art. 62.

[163] Spectar, *supra* note 162, at 90.

[164] Antarctic Protection Act of 1990, P.L. No. 101-594, 104 Stat. 2975 (1990).

[165] *See U.S. Raises Objections To Antarctica Pact*, N.Y. TIMES, June 18, 1991, at C6.

[166] Protocol on Environmental Protection to the Antarctic Treaty, art. VII, Oct. 4, 1991, 30 I.L.M. 1455, 1461, art. 2.

[167] *Id.* at art. 7.

[168] *Id.* at art. 25(3).

[169] *Id.* at art. 25(5)(b).

[170] *See* Mohamed Haron, *The Ability of the Antarctic System to Adapt to External Challenges*, *in* ANTARCTIC TREATY SYSTEM IN WORLD POLITICS, 299, 303 (A.J. Dahl & W. Ostreng eds., 1991).

al obstacles to any change. Also, a stronger moratorium arguably would not survive the pressure for exploitation that would follow if scientific research led to a high-value resource discovery.[171]

3. Nuclear Weapons Testing

The United States, Soviet Union, and United Kingdom conducted hundreds of atmospheric nuclear-weapons tests in the 1950s, sparking global calls to ban testing.[172] When negotiations for a test ban began in 1958, all three states adopted temporary testing moratoria.[173] They dropped their moratoria and resumed testing in 1961 after negotiations stalled in response to rising U.S.-Soviet tensions and France's first test,[174] but were still able to negotiate the Limited Test Ban Treaty in 1963.[175] The next fifteen years saw modes progress and several agreements limiting testing by location or size.[176]

By the late 1980s, the decline of the Cold War reduced states' need to develop new weapons and prompted renewed calls for a comprehensive test ban.[177] In the Soviet Union, a growing anti-nuclear movement,[178] including protests over radiation leaks from a sloppy 1989 test, led to decisions in 1991 to close the main test site[179] and announce a moratorium.[180] Spurred by high-profile anti-nuclear protests and the rise of the Green Party, France

[171] *Accord* PETER J BECK, THE INTERNATIONAL POLITICS OF ANTARCTICA __ (2014).

[172] JONATHAN E. MEDALIA, COMPREHENSIVE NUCLEAR-TEST-BAN-TREATY: BACKGROUND AND CURRENT DEVELOPMENTS, CONG. RES. RPT. 7-5700 1 (2014).

[173] Pierce S. Corden, *Historical Context and Steps to Implement the CTBT, in* BANNING THE BANG OR THE BOMB? NEGOTIATING THE NUCLEAR TEST BAN REGIME 17, 19 (Mordechai Melamud, Paul Meerts & I. William Zartman eds., 2014).

[174] Fen Osler Hampson, *The Importance of Coupling: The Limited Test Ban Negotiations, in* BANNING THE BANG OR THE BOMB? NEGOTIATING THE NUCLEAR TEST BAN REGIME 87 (Mordechai Melamud, Paul Meerts & I. William Zartman eds., 2014).

[175] Treaty Banning Nuclear Weapons in the Atmosphere, in Outer Space and Under Water, Aug. 5, 1963, 14 U.S.T. 1313, 480 U.N.T.S. 43.

[176] Hampson, *supra* note 174, at 89; MEDALIA, *supra* note 172, at 1; Treaty on the Limitation of Underground Nuclear Weapon Tests, U.S.-U.S.S.R., July 3, 1974, 13 I.L.M. 906; Treaty on Underground Nuclear Explosions for Peaceful Purposes, U.S.-U.S.S.R., May 28, 1976, 15 I.L.M. 891 (1976), 1714 U.N.T.S. 387.

[177] MEDALIA, *supra* note 172, at 1.

[178] Rebecca Johnson, *The Role of Civil Society in Negotiating the CTBT, in* BANNING THE BANG OR THE BOMB? NEGOTIATING THE NUCLEAR TEST BAN REGIME 96, 106 (Mordechai Melamud, Paul Meerts & I. William Zartman eds., 2014).

[179] *Id.* at 106.

[180] Japp Ramaker, *The Negotiating Process, 1994-1196: A View from the Chair, in* BANNING THE BANG OR THE BOMB? NEGOTIATING THE NUCLEAR TEST BAN REGIME 58, 64 (Mordechai Melamud, Paul Meerts & I. William Zartman eds., 2014).

announced a moratorium one year later.[181] This in turn influenced the U.S. Congress to approve a one-year moratorium, which halted testing until at least July 1, 1993 with specified conditions for subsequent resumption by presidential action.[182] With negotiations for a full test ban then underway, President Clinton subsequently extended the moratorium until the resultant treaty entered into force.[183]

The Comprehensive Nuclear-Test-Ban Treaty (CTBT), which obliges parties "not to carry out any nuclear weapon test explosion or any other nuclear explosion," was adopted by the General Assembly in 1996.[184] To enter into force, the treaty requires ratification by all forty-four states with nuclear technology.[185] Of these, India, North Korea, and Pakistan have not signed, while China, Egypt, Iran, Israel, and the United States have not ratified.[186] Yet even without a legally binding obligation, unilateral moratoria have mostly succeeded at preventing tests. France resumed testing in 1995, but soon reinstated its moratorium after international protests.[187] Russia has conducted low-yield experiments that it claims (against widespread criticism) are consistent with the CTBT.[188] The United States adopted a program in 2002 to reduce the time needed to resume testing,[189] and stated it would resume testing if needed to "diagnose or remedy a problem in a warhead critical to the U.S. nuclear deterrent . . . ," but has not done so.[190] In-

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[181] Johnson, *supra* note 181, at 102.

[182] *See id.*; Energy and Water Development Appropriations Act of 1993, P.L. 102-377, §507, 106 Stat. 1315, 1343-44 (1992).

[183] Johnson, *supra* note 181, at 106.

[184] Comprehensive Nuclear Test Ban Treaty [hereinafter CTBT], art. I. Sept. 24, 1996, 35 I.L.M. 1439, adopted in G.A. Res. 50/245, U.N. Doc. A/RES/50/245 (Sept. 17, 1996). *But see* David S. Jonas, *The Comprehensive Nuclear Test Ban Treaty: Current Legal Status in the United States and the Implications of a Nuclear Test Explosion*, 39 INTL. L. & POLITICS 1007, 1016 (2007); *cf.* Legality of the Threat of Use of Nuclear Weapons, Advisory Op., 1996 I.C.J. 266 (July 8).

[185] CTBT, *supra* note 187, art. XIV.

[186] *See* U.N. TREATY COLLECTION, https://treaties.un.org/Pages/showDetails.aspx?objid=0800000280049f7f (last visited Dec. 1, 2015).

[187] *See* Ramaker, *supra* note 183, at 64; CTBTO PREPARATORY COMM'N, *Fifteenth Anniversary of France's Last Nuclear Test*, http://www.ctbto.org/press-centre/highlights/2011/fifteenth-anniversaryof-frances-last-nuclear-test/ (last visited Jan. 28, 2015).

[188] MEDALIA, *supra* note 175, at 8.

[189] *See* U.S. Dept. of Defense, News Transcript, *Special Briefing on the Nuclear Posture Review*, Jan. 9, 2002, *available at* http://www.defense.gov/transcripts/transcript.aspx?transcriptid=1108.

[190] MEDALIA, *supra* note 175, at 4 (quoting Letter from Condoleezza Rice, Sec'y of State, to Hon. Pete Domenici, U.S. Senate, June 25, 2007). *See also* Pres. Dec. Dir. 15 (1993), *available at* http://www.fas.org/irp/offdocs/pdd/pdd-15.pdf.

deed, states' interests in testing may be declining, as stockpile stewardship technologies let them maintain confidence in their capacity without testing.[191] Controversy persists, however, over whether stockpile stewardship falls within the meaning of the term "nuclear test" in the CTBT, or is otherwise contrary to the spirit of the agreement.[192]

Unilateral moratoria appear to have helped reduce testing in two ways: facilitating negotiation of formal limits in the 1963 and 1996 treaties, by signaling cooperation and showing the practicality of stopping tests;[193] and establishing a de facto international norm against testing, even absent a legal obligation.[194] Nearly all weapons states remain committed to unilateral moratoria, even in the face of tests by the one state with no moratorium, North Korea.[195] Indeed, the global outcries that met North Korea's tests and France's brief 1995 retreat from its moratorium, demonstrate states' political incentives to maintain their commitments.

4. U.S.-Mexico Transboundary Oil and Gas Reservoirs

In 1978, the United States-Mexico Treaty on Maritime Boundaries apportioned most of the Gulf of Mexico between the two states.[196] Falling outside both states' exclusive economic zones, however, was a 4.5-million-acre triangle in the deep center of the Gulf known as the "Western Gap," believed to contain large oil and gas resources.[197]

By the 1990s, resource discoveries and advances in deep drilling fueled a surge in U.S. developments in deep Gulf waters, and U.S. producers began to express interest in sites in the Western Gap.[198] By contrast, Mexi-

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[191] *See* Chris McIntosh, *Framing the CTBT Debate Over the US Ratification of the Treaty*, *in* BANNING THE BANG OR THE BOMB? NEGOTIATING THE NUCLEAR TEST BAN REGIME 146, 153-54 (Mordechai Melamud, Paul Meerts & I. William Zartman eds., 2014).

[192] MEDALIA, *supra* note 175, at 8, 23, 34, 42-43, 48.

[193] *See* Johnson, *supra* note 181, at 106; Mordechai Melamud, Paul Meerts & I. William Zartman, *Lessons from the CTBTO Negotiation Process, in* NEGOTIATING THE NUCLEAR TEST BAN REGIME 341, 342 (Mordechai Melamud, Paul Meerts & I. William Zartman eds., 2014).

[194] *See* JOINT MINISTERIAL STATEMENT ON THE CTBT (Sept. 27, 2012), *available at* http://www.mofa.go.jp/policy/un/disarmament/ctbt/friends_minstate1209.html.

[195] JOINT STATEMENT TO THE 2010 NON-PROLIFERATION TREATY REVIEW CONFERENCE BY THE FIVE PERMANENT MEMBERS OF THE UNITED NATIONS SECURITY COUNCIL (2010), *available at* http://www.state.gov/r/pa/prs/ps/2010/05/141547.htm.

[196] Treaty on Maritime Boundaries between the United States of America and the United Mexican States, May 4, 1978, 17 I.L.M. 1073 (1978).

[197] S. Rep. No. 105-4 (1997).

[198] *See* Miriam Grunstein, Richard McLaughlin & Luis Anastacio Gutiérrez, *Gulf of Mexico Offshore Transboundary Hydrocarbon Development: Legal Issues Between Mexico*

co's state oil company Pemex lacked the technology and capital to do deepwater exploration, and was prohibited from partnering with foreign firms that could provide these.[199] Without a regime for transboundary resources, Mexico feared U.S. companies would drain reservoirs from the U.S. side—by the *efecto popote* or "straw effect."[200]

In 1997, the United States announced it would not lease tracts in the Western Gap until the countries reached agreement on resources in the area. Negotiations began soon thereafter, and concluded with the 2000 adoption of the Western Gap Treaty.[201] The treaty defines the boundary in the Western Gap and establishes a framework for cooperation on cross-border reservoirs.[202] Article 4 establishes a ten-year moratorium (later extended to 2014) on drilling in a buffer zone 1.4 nautical miles on either side of the new boundary, to ensure neither state can exploit shared resources.[203]

In 2012, the two states signed another treaty that establishes a more detailed regime for cooperative development of transboundary resources.[204] With full implementation of this treaty the moratorium was ended,[205]and the United States began issuing leases in the transboundary area in 2014.[206]

By assuaging long-standing Mexican concerns, the moratorium gave the two states time to negotiate details of trans-boundary development. This initial political concession may have smoothed Mexican ratification of the

& the U.S., 50-DEC HOUS. LAW. 22, 22 (2012).

[199] Clare Ribando Seelke et al., *Mexico's Oil and Gas Sector: Background, Reform Efforts, and Implications for the United States*, CONG. RESEARCH SERV. REP. NO. R43313 2-3 (2015).

[200] Jose A. Vargas, *The 2012 U.S.-Mexico Agreement on Transboundary Hydrocarbon Reservoirs in the Gulf of Mexico: A Blueprint for Progress or a Recipe for Conflict?*, 14 SAN DIEGO INT'L L.J. 3, 37 (2012).

[201] Treaty on the Delimitation of the Continental Shelf in the Western Gulf of Mexico Beyond 200 Nautical Miles, U.S.-Mex., art. 1, June 9, 2000, 2143 U.N.T.S. 417 [hereinafter Western Gap Treaty].

[202] *Id.* at art. 4.

[203] *Id.* at art. 4; Dabney Welsh, *Access to Our Backyard Reserves: A Final Resolution of the Western Gulf of Mexico's Maritime Boundaries*, 23 HOUS. J. INT'L L. 609, 651-52 (2001).

[204] Agreement between the United States of America and the United Mexican States Concerning Transboundary Hydrocarbon Aquifers in the Gulf of Mexico, Feb. 20, 2012 [hereinafter 2012 Treaty]. *See also* Bipartisan Budget Act of 2013, tit. III, H.J. RES. 59 (2013) (approving the 2012 Treaty).

[205] 2012 Treaty, *supra* note 208, at ch. 7.

[206] Clare Ribando Seelke et al., *Mexico's Oil and Gas Sector: Background, Reform Efforts, and Implications for the United States*, CONG. RESEARCH SERV. REP. NO. R43313, at 17 (2015).

2000 Western Gap Treaty.[207] It also provided time for President Calderón to build support for letting the Mexican oil industry partner with foreign companies.[208] For its part, the United States gained Mexican ratification—necessary for development in the U.S. portion of the Gap—in return for the limited sacrifice of a delay in developing the buffer zone, with no loss to long-term interests. The moratorium thus benefited both sides by facilitating a negotiated agreement and limiting risk of exploitation in the interim.

5. Ocean Dumping of Low-Level Radioactive Waste

From the 1940s through the early 1980s, countries routinely disposed of radioactive wastes in the oceans.[209] Although dumping initially included high-level wastes—spent reactor fuel and other highly radioactive materials—this practice was prohibited by the 1972 London Convention.[210] The Convention did not prohibit dumping low-level wastes, which are less hazardous than high-level wastes but generated in larger volumes, so land-based processing is expensive.[211] Several nations continued to dump low-level wastes,[212] and scientists largely believed this posed minimal environmental risks.[213]

In 1978, Greenpeace launched a campaign against dumping any radioactive waste, based on claims of health and environmental risks.[214] The campaign gained support from several nations that did not dump and were concerned about risks to coastal and marine environments, including Spain, the Nordic states, and several Pacific island states.[215] In response, Convention

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[207] Vargas, *supra* note 203, at 41.

[208] *Id.* at 68-89.

[209] *See* John Warren Kindt, *Radioactive Wastes*, 24 NATURAL RESOURCES J. 967, 974-76 (1984).

[210] London Convention, *supra* note 88, at art, IV & annex I, para. 6.

[211] *See* NUCLEAR ENERGY AGENCY, ORG. ECON. COOPERATION & DEV., LOW-LEVEL RADIOACTIVE WASTE REPOSITORIES: AN ANALYSIS OF COSTS (1999), *available at* https://www.oecd-nea.org/rwm/reports/1999/low-level-waste-repository-costs.pdf; Kindt, *supra* note 213, at 972-73.

[212] *See* Alan Sielen, *The New International Rules on Ocean Dumping: Promise and Performance*, 21 GEO. INT'L ENVTL. L. REV. 295, 317 (2009).

[213] *See, e.g.*, INT'L ATOMIC ENERGY AGENCY, RADIOACTIVE WASTE DISPOSAL INTO THE SEA 77 (1961); Nat'l Oceanic & Atmospheric Admin., *The Assimilative Capacity of U.S. Coastal Waters for Pollutants*, Proceedings of a Workshop at Crystal Mountain, Washington, July 29-Aug. 4, 1979 (1979).

[214] Remi Parmentier, *Greenpeace and the Dumping of Wastes at Sea: A Case of Non-State Actors' Intervention in International Affairs*, 4 INT'L NEGOTIATION 1, 2 (1999). *See also* LDC 7/12, 7.24.

[215] Edward L. Miles, *Sea Dumping of Low-Level Radioactive Waste, 1964 to 1982, in* ENVIRONMENTAL REGIME EFFECTIVENESS: CONFRONTING THEORY WITH EVIDENCE

parties adopted a voluntary moratorium on dumping all radioactive materials in 1983, pending an expert risk assessment to be presented to the parties in 1985.[216] Greenpeace expressed doubt that a scientific assessment could sway those parties determined to keep dumping, while also noting that dumping raised political, social, and moral issues in addition to its environmental risks—suggesting that they too might be unmoved by scientific assessment.[217] The United Kingdom and Russia continued to dump low-level wastes during the moratorium,[218] while Japan—which had switched low-level disposal from ocean to rivers in 1969—sought to resume dumping in the Pacific.[219] The United States, which had stopped dumping in 1970 on deciding it was not the cheapest disposal option, observed the moratorium.[220]

When the 1985 assessment reached no conclusion on risks of low-level dumping, parties passed a resolution to extend the voluntary moratorium indefinitely. The resolution also created a new expert panel tasked with providing further information on "scientific, political, legal, economic, and social dimensions" of dumping by 1993.[221] Support for the moratorium remained uneven: The United States and United Kingdom both stressed its voluntary nature, while Russia and Japan declined to sign the resolution.[222]

Disagreement persisted during the second moratorium period, but momentum gradually shifted against dumping. While the United Kingdom and France lobbied against strengthening the moratorium to a ban, Japan and the United States reversed to support a permanent binding prohibition.[223] Pub-

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87, 105-06 (Edward L. Miles et al. eds., 2002).

[216] Res. LDC.14(7), Disposal of Radioactive Wastes and Other Radioactive Matter at Sea (LDC 7/12, annex 3); Mechanism for the Preparation of an Expert Meeting on Radio-Active Matters Related to the London Dumping Convention (LDC 7/12, annex 6).

[217] LDC 7/12, 7.24

[218] *See generally* Alexey V. Yablokov, *Radioactive Waste Disposal in Seas Adjacent to Territory of the Russian Federation*, 43 MARINE POLLUTION BULL. 8 (2001); Ursula Wasserman, *Disposal of Radioactive Waste*, 19 J. WORLD TRADE 425, 427 (1985).

[219] *See* Steven D. Lavine, *Russian Dumping in the Sea of Japan*, 24 DENV. J. INT'L L. & POL'Y 417, 435 (1996); Robert Trumbell, *Song of the South Pacific Islanders: Don't Dump it Here*, N.Y. TIMES, Sept. 2, 1984.

[220] *See* OFF. RADIATION PROG., U.S. ENVTL. PROTECTION AGENCY, FACT SHEET ON OCEAN DUMPING OF RADIOACTIVE WASTE MATERIALS 3 (1980. *But see Oceans Suggested at Dumps*, N.Y. TIMES, July 24, 1984.

[221] Res. LDC.21(9), Dumping of Radioactive Wastes at Sea (LDC 9/12, annex 4); Res. LDC.28(10), Studies and Assessments Pursuant to Resolution LDC 21(9) (LDC 10/15, annex 11).

[222] *See* Lavine, *supra* note 224, at 427.

[223] *See id.* at 435, 437, 448; David E. Pitt, *Nations Back Ban on Atomic Dumping*, N.Y. TIMES, Nov. 13, 1993.

lic pressure moved some countries to find alternative disposal methods. The United Kingdom, for example, planned to continue violating the moratorium, but was forced to stop when its seafarers' union refused to handle radioactive waste.[224]

Russia blatantly violated the moratorium. In contrast to Russia's official position during the moratorium that it had not dumped and did not plan to, a 1993 report disclosed that the Soviet Union had dumped routinely and Russia planned to continue.[225] In October 1993, Russia dumped hundreds of tons in the Sea of Japan, with no attempt at concealment.[226] When charged by Greenpeace with violating international law, the Russian Environment Minister replied that there was no violation because the Convention did not prohibit such dumping, the moratorium was voluntary, and Russia had not joined it.[227]

The expert assessment was little help in resolving these disputes. Over six years work, the Panel found no evidence of significant impacts from dumping, but balanced this conclusion with general statements about the importance of protecting the marine environment. Parties were thus able to use its ambiguous reports to support opposing positions,[228] but most national positions had shifted away from dumping by that time. At their 1993 meeting, parties amended the Convention to ban dumping of any radioactive wastes, with provision for review at 25-year intervals.[229] Five countries abstained—Russia, China, the United Kingdom, France, and Belgium—but none voted against the ban,[230] which was subsequently incorporated into the 1996 London Protocol.[231]

While they observed the ban, the United Kingdom, France, and Japan

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[224] *See Ban is Extended on Dumping of Hazardous Waste at Sea*, N.Y. TIMES, Feb. 26, 1984.

[225] *See* Yablokov, *supra* note 223.

[226] David E. Sanger, *Nuclear Material Dumped Off Japan*, N.Y. TIMES, Oct. 19, 1993, at A1.

[227] Lavine, *supra* note 224, at 427 (quoting *Press Conference by Viktor Danilov-Danilyan and Yuri Yarov, Candidates for the State Duma from the Political Bloc Vybor Rossii (Russia's Choice) on Russian Federation Environmental Problems*, Official Kremlin International News Broadcast, Nov. 22, 1993).

[228] Kirsti-Liisa Sjoblom & Gordon Linsley, *Sea Disposal of Radioactive Wastes: The London Convention 1972*, 2 IAEA BULLETIN 12, 15 (1994).

[229] Res. LC.51(16), Amendments to the Annexes to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 Concerning Disposal at Sea of Radioactive Wastes and Other Radioactive Matter (LC 16/14, annex 5).

[230] Report of the Sixteenth Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, 4.41, Dec. 15, 1993 [hereinafter Convention Rpt.].

[231] *See* London Protocol, *supra* note 90, at art. 4.

continued to argue it was a needless concession to public fears, and that ocean disposal was the most environmentally sound approach to low-level waste.[232] Russia initially stated it planned to continue dumping[233] but changed plans on receiving a promise of Japanese aid to build a processing facility in Eastern Russia and became bound by the ban on withdrawing its objection in 2005.[234]

Adopted under substantial disagreement, the voluntary moratorium was ostensibly a response to uncertain environmental risk, to be resolved based on scientific assessment. Multiple assessments, however, were unable to draw clear conclusions on risk or provide a basis for policy. Instead, even those states most attached to dumping eventually succumbed to sustained political pressure and the moratorium hardened into a ban.

6. Commercial Whaling

By the mid-twentieth century, uncontrolled whaling had brought collapse of most commercial whale stocks. In response, fifteen whaling nations in 1946 adopted the International Convention for the Regulation of Whaling (ICRW), which established the International Whaling Commission (IWC).[235] The IWC was charged to ensure orderly development of the whaling industry[236] by establishing catch limits, based on advice from a Scientific Committee and adopted or changed by three-quarters majority vote.[237]

Over the next three decades, the whaling industry was buffeted by declining demand, technological change, and the growth of environmentalism.[238] Its greatest challenge came from worldwide "save the whales" campaigns, motivated by concerns about both species survival and the ethics of whaling.[239] Conflict over whaling played out in the politics of harvest limits and IWC membership. Through the 1960s, the IWC ignored its Scientific Committee's advice and set catch limits unsustainably high. Stocks declined and opposition to whaling intensified.[240] The United States, for-

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[232] *See* Lavine, *supra* note 224, at 441-42.
[233] *See* Pitt, *supra* note 228.
[234] *See* Lavine, *supra* note 228, at 443-48.
[235] International Convention for the Regulation of Whaling [hereinafter ICRW], Preamble, Dec. 2, 1946, 62 Stat. 1716, 161 U.N.T.S. 72.
[236] *Id.*
[237] *Id.* at art. III(2)
[238] *See* PATRICIA BIRNIE, INTERNATIONAL REGULATION OF WHALING __ (1985).
[239] A. D'Amato & S. Chopra, *Whales: Their Emerging Right to Life*, 85 AM J. INT'L L. 21, __ (1991).
[240] William C. Burns, *The International Whaling Commission and the Future of Cetaceans:*

merly a major whaling state, prohibited trade in whale products in 1972.[241] The same year, the U.N. Conference on the Human Environment recommended a ten-year moratorium.[242] Anti-whaling states joined the IWC, shifting control away from whaling states, and the United States and Australia led anti-whaling states in proposing a moratorium on commercial whaling.[243]

By 1982, IWC membership had grown to 37 states and anti-whaling forces pushed through a decision setting all commercial catch limits to zero, based on concerns about extinction, uncertain population data, and the humaneness of whaling.[244] This de facto moratorium took effect in 1986, to be re-assessed based on a 1990 report on sustainable catch levels from the Scientific Committee.[245]

Both the ICRW text and the moratorium decision state that catch limits should be based on scientific advice,[246] but the Scientific Committee's assessments of stocks and safe catch levels have had little influence on parties' positions on the moratorium.[247] Their 1990 report concluded that some stocks could be sustainably harvested with quotas,[248] but parties declined to lift the moratorium until new management procedures were adopted to ensure catch limits were observed.[249] This decision prompted outrage from whaling states and the resignation of the Scientific Committee's chairman.[250] Discussion on these management procedures has stalled since, as

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Problems and Prospects, 8 COLO. J. INT'L ENVTL. L. & POL'Y 31, 35-42 (1997).

[241] *See, e.g.*, 50 C.F.R. § 17.11; Marine Mammal Protection Act, Pub. L. No. 92-522, 86 Stat. 1027 (1972) (codified as amended at 16 U.S.C. §§ 1361-1421).

[242] Report of United Nations Conference on the Human Environment, Recommendation 33, at 12, U.N. Doc. A/Conf. 48/14 (1972).

[243] *See* Lieberman, Gray & Groom, *supra* note 99, at 525.

[244] IWC Schedule, ¶10(d)-(e). The resolution passed by a vote of 25 to 7, with 5 abstentions. THIRTY-THIRD REPORT OF THE INTERNATIONAL WHALING COMMISSION 21 (1983).

[245] IWC Schedule, ¶10(d)-(e).

[246] THIRTY-THIRD REPORT OF THE INTERNATIONAL WHALING COMMISSION, *supra* note 250, at 20-21; ICRW, *supra* note 240, at art. V(2).

[247] *See* A.W. Harris, *The Best Scientific Evidence Available: The Whaling Moratorium and Divergent Interpretations of Science*, 29 WM. & MARY ENVTL. L. & POL'Y REV. 375, 377 (2005).

[248] *See Report of the Scientific Committee*, 41 REP. INT'L WHALING COMM'N 51, 62-63 (1991).

[249] *See generally Revised Management Procedure (RMP)*, INT'L WHALING COMM'N (2015), https://iwc.int/rmp.

[250] *See* David D. Caron, *The International Whaling Commission and the North Atlantic Marine Mammal Commission: The Institutional Risks of Coercion in Consensual Structures*, 89 AM. J. INT'L L. 154, 162-67 (1995).

anti-whaling parties continue to block attempts to lift the moratorium.[251]

The moratorium is not a complete prohibition, but includes exceptions that allow some whaling to continue. It only covers commercial whaling, allowing whaling for research or aboriginal subsistence.[252] In addition, any state may claim an exemption from an IWC decision by objecting within ninety days.[253] Japan, Norway, the Soviet Union, and Peru objected to the moratorium, although Japan and Peru later withdrew their objections.[254] Japan has kept whaling throughout the moratorium, first based on its objection, then at lower levels (still thousands of whales) under the research exception.[255] Iceland left the IWC in 1992 and rejoined in 2002, with a reservation to the moratorium whose legality is disputed.[256] Norway resumed whaling in 1993, as its objection allows, and also joined Iceland, Greenland, and the Faroe Islands to establish a new international whaling institution.[257]

The issue remains deadlocked. The moratorium remains formally in place while the most determined whaling states find ways to continue commercial harvests—albeit at much lower levels than before the moratorium. Japan, Iceland, and Norway continue to advocate resumed whaling in the IWC, where there are recent signs anti-whaling forces may be losing their safe majority. Japan continuously recruits pro-whaling states to join, and is regularly accused of buying votes with aid to small states.[258] The intensity of continuing conflict, including periodic violent confrontations at sea between whaling vessels and anti-whaling groups,[259] has led many observers to speculate that the regime is not sustainable.[260]

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[251] *See Revised Management Procedure (RMP)*, INT'L WHALING COMM'N (2015), https://iwc.int/rmp.

[252] ICRW, *supra* note 240, at art. 8; IWC Schedule, ¶10(d)-(e).

[253] ICRW, *supra* note 240, at art. 5(3)(a).

[254] IWC Schedule, ¶10(e) (accompanying note).

[255] *See* Burns, *supra* note 246, at 45, 49, 80. *See also* Whaling in the Antarctic (Austl. v. Japan: N.Z. Intervening), Judgment, 2014 I.C.J. 226 (March 31, 2014); Assoc. Press in Tokyo, *Japan Plans Unilateral Restart to Antarctic Whaling in 2015, Says Official*, GUARDIAN, June 20, 2015, http://www.theguardian.com/environment/2015/jun/20/japan-plans-unilateral-restart-to-antarctic-whaling-in-2015-says-official.

[256] *See* INT'L WHALING COMM'N, *Iceland and Commercial Whaling*, https://iwc.int/Iceland (2015).

[257] *See* Agreement on Cooperation in Research, Conservation and Management of Marine Mammals in the North Atlantic, Apr. 9, 1992, 1945 U.N.T.S. 3.

[258] *See* Burns, *supra* note 246, at 35.

[259] *See, e.g.*, *Wars over Whaling*, Editorial, JAPAN TIMES, Jan, 15, 2012; *Sea Shepherd Accuses Japanese Whalers of 'Aggressive', 'Ruthless' Confrontation*, GUARDIAN, Feb. 2, 2014.

[260] *See, e.g.*, Lieberman, Gray & Groom, *supra* note 99, at 528; Oran R. Young et al., *Sub-*

7. Intellectual Property Non-Violation Complaints under WTO

Several treaties in the world trade regime, including the General Agreement on Tariffs and Trade (GATT), allow World Trade Organization (WTO) members to file a "non-violation complaint" against another state whose actions impair a reasonably expected treaty benefit, even if the actions do not violate a treaty.[261] GATT founders allowed non-violation complaints because many measures unregulated by a tariff treaty, such as domestic subsidies, can disrupt competition between domestic and imported goods and so frustrate treaty goals.[262] Non-violation complaints are especially controversial in the area of intellectual property rights.[263] Due to sharp disagreement, mainly along North-South lines, the 1994 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) includes a moratorium on non-violation complaints.[264]

TRIPS aims to establish minimum standards of intellectual property (IP) rights protection and enforcement for all members.[265] Its negotiations were difficult and the treaty remains controversial, reflecting the importance of technology in trade, and variation among states in technological capacity and how they value IP rights.[266] Some states argued that standards for IP differ from other trade commitments in ways that make non-violation complaints inappropriate. The main concern was that non-violation complaints could create *de facto* IP standards stricter than states have accepted in negotiations.[267] The European Union, for example, feared the United States might file non-violation complaints to demand access to EU markets, when

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sistence, Sustainability, and Sea Mammals: Reconstructing the International Whaling Regime, 23 OCEAN & COASTAL MGMT. 117, 124 (1994).

[261] *See, e.g.*, General Agreement on Tariffs and Trade 1994 arts. XXII &, XXIII, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1A, 1867 U.N.T.S. 187, 33 I.L.M. 1153 (1994); General Agreement on Trade in Services art. XXIII(3), Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1B, 1869 U.N.T.S. 183, 33 I.L.M. 1167 (1994).

[262] Frieder Roessler & Petina Gappah, *A Re-Appraisal of Non-Violation Complaints, in* THE WORLD TRADE ORGANIZATION: LEGAL, ECONOMIC AND POLITICAL ANALYSIS 1371, 1374 (P. Macrory, A. Appleton & M. Plummer eds., 2005).

[263] U.N. CONF. ON TRADE & DEVELOPMENT & INT'L CTR. FOR TRADE & SUSTAINABLE DEVELOPMENT [hereinafter UCTAD-ICTSD], RESOURCE BOOK ON TRIPS AND DEVELOPMENT 674-75, 680-82 (2005).

[264] *See* Agreement on Trade-Related Aspects of Intellectual Property Rights, art. 64.2, Apr. 15, 1994, 33 I.L.M. 1125 [hereinafter TRIPS]; UCTAD-ICTSD, *supra* note 269, at 663-64.

[265] *See* TRIPS, *supra* note 270, at Preamble.

[266] *See* Peter K. Yu, *The Objectives and Principles of the Trips Agreement*, 46 HOUS. L. REV. 979, 980 (2009).

[267] *See* UCTAD-ICTSD, *supra* note 269, at 663-64, 674-75.

TRIPS provides only protection of IP rights in that market.[268] Developing countries feared non-violation complaints against their drug price-control regulations, even though TRIPS does not address price controls.[269] In contrast, the United States and Switzerland argued non-violation complaints are necessary to prevent members from undermining TRIPS through inappropriately narrow interpretations of its scope.[270] After heated debate with little progress, negotiators adopted a five-year moratorium on non-violation complaints.[271]

The moratorium successfully delayed conflict that threatened adoption of TRIPS, but there has since been little progress.[272] Instead, parties have repeatedly extended the moratorium without substantive discussion,[273] and the full range of resolutions—allow complaints with various processes to resolve them, ban them, or continue the moratorium—remains on the table.[274] The moratorium thus provides a continuing, partial victory that serves the interests of the majority of members in the absence of a negotiated resolution.

B. Moratoria for Controversial Science and Technology

A second subject-matter area where moratoria are frequently proposed is in controversial areas of scientific research or technology. We review five cases, all related to advances in biomedical research and its applications. This imbalance in scientific fields is not our choice, but reflects the greater controversy over advances in biomedical science over recent decades.

1. Recombinant DNA Research

The early 1970s development of recombinant DNA (rDNA) techniques promised vast advances in scientific understanding and clinical applications. These techniques made it possible to remove, insert, or combine genetic

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[268] Frederick M. Abbott, *TRIPS in Seattle: The Not-So-Surprising Failure and the Future of the TRIPS Agenda*, 18 BERKELEY J. INT'L L. 165, 172-73 (2000).

[269] *Id.* at 172.

[270] UCTAD-ICTSD, *supra* note 269, at 663; *TRIPS: 'Non-Violation' Complaints (Article 64.2) Background and Current Situation*, WORLD TRADE ORG., http://www.wto.org/english/tratop_e/trips_e/nonviolation_background_e.htm (last visited Nov. 20, 2015).

[271] UCTAD-ICTSD, *supra* note 269, at 663-64. *See* TRIPS, *supra* note 270, at art. 64.2.

[272] *See* Abbott, *supra* note 274, at 173.

[273] Ministerial Decision of 19 December 2015: WT/MIN(15)/41 — WT/L/976.

[274] *TRIPS: 'Non-Violation' Complaints (Article 64.2) Background and Current Situation*, *supra* note 276.

material from different sources. Publication of the first successful rDNA manipulations in 1972[275] triggered alarm among researchers, about risks and other implications of the work. After discussion of the new capabilities at a June 1973 Gordon Research Conference, conference organizers wrote to the National Academy of Sciences (NAS) president, proposing a committee to assess risks of rDNA research and recommend research guidelines to control them.[276] Concerns included health and environmental risks from altered organisms that might escape the lab, and potential misuse of the ability to manipulate the genetic basis of life.[277]

The NAS committee, comprised of a dozen eminent scientists, submitted a report in July 1974 recommending that:

> until the potential hazards of [rDNA] molecules have been better evaluated or until adequate methods are developed for preventing their spread, scientists throughout the world join with the members of this committee in voluntarily deferring [two] types of experiments [judged to pose the most severe hazards].[278]

The immediate aim of the moratorium was to allow time to convene an international scientific meeting to further consider risks and responses.[279] The report also called on the National Institutes of Health (NIH) to develop operational guidelines to minimize risks of rDNA research.[280] Although some researchers disputed that the hazards were severe enough to warrant the voluntary moratorium, they nevertheless universally observed it.[281]

The international meeting convened in February 1975 at Asilomar, California, gathering scientists, lawyers, officials, and journalists.[282] The meeting report categorized experiments by estimated risk and recommended safety measures that varied accordingly, with many elements based on ex-

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[275] *See, e.g.*, David A. Jackson, Robert H. Symons & Paul Berg, *Biochemical Method for Inserting New Genetic Information into DNA of Simian Virus 40: Circular SV40 DNA Molecules Containing Lambda Phage Genes and the Galactose Operon of* Escherichia coli, 69 PROC. OF THE NAT'L ACADEMY OF SCIENCES 2904 (1972); J.E. Mertz & R.W. Davis, *Cleavage of DNA by R1 Restriction Endonuclease Generates Cohesive Ends*, 69 PROC. NAT'L ACAD. SCI. 3370 (1972).

[276] Maxine Singer & Dieter Soll, *Guidelines for DNA Hybrid Molecules*, 181 SCI. 1114 (1973).

[277] *See id*.; Paul Berg & Maxine F. Singer, *The Recombinant DNA Controversy: Twenty Year Later*, 92 PROC. NAT'L ACAD. SCI. 9011, 9011 (1995).

[278] The committee's letter report was simultaneously published as Paul Berg et al., *Potential Biohazards of Recombinant DNA Molecules*, 185 SCI. 303 (1974).

[279] *Id.* at 303.

[280] *Id.*

[281] Berg & Singer, *supra* note 284, at 9011.

[282] *Id*.

isting laboratory practices for research on highly infectious agents.[283] The conference concluded the moratorium should be lifted and rDNA research resumed with these safety measures, except for two types judged too risky given available control capabilities.[284] Just as the moratorium was adopted over some objection, Asilomar participants made the decision to narrow the moratorium over strong opposition from a minority.[285] As Berg recounts, "[s]ome scientists, and public officials as well, were certain that recombinant DNA research was flirting with disaster and that lifting the moratorium was a blunder. . . ."[286]

NIH had already established a Recombinant DNA Advisory Committee (RAC) to develop guidelines for federally funded research, which began work right after Asilomar. Despite skepticism from scientists, the NIH Director insisted that work on the guidelines include public hearings.[287] Although NIH only had authority over federally funded research, the RAC developed the guidelines expecting that all researchers and funders would observe them. Judging it crucial to retain flexibility and to issue the guidelines quickly lest support for the still-voluntary Asilomar guidelines erode,[288] NIH decided not to issue the guidelines as binding regulations.[289] They were nevertheless adopted by all federal research agencies, and by most private biotechnology firms—who were eager to signal prudence and avoid the tighter constraints being proposed in Congressional bills.[290] NIH began revising the guidelines within months of their release, as evidence mounted that Asilomar participants and the RAC had overestimated risks of research.[291]

The voluntary moratorium was a reaction to acute uncertainty about

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[283] Paul Berg et al., *Summary Statement of the Asilomar Conference on Recombinant DNA Molecules*, 72 PROC. NAT'L ACAD. SCI. 1981, 1982 (1975).

[284] Berg et al., *supra* note 291, at 1981. The exceptions were rDNA from highly pathogenic organisms, and experiments using more than 10 liters of culture. *Id.* at 1983.

[285] Berg & Singer, *supra* note 284, at 9011.

[286] *Id.*

[287] D.S. Fredrikson, *A History of the Recombinant DNA Guidelines in the United States*, *in* RECOMBINANT DNA AND GENETIC EXPERIMENTATION 151, 152 (W. J. Whelan & Joan Morgan eds., 1979).

[288] H. DeWitt Stetten, Jr., *The Early History of the Recombinant DNA Molecule Program Advisory Committee of NIH, in* RECOMBINANT DNA AND GENETIC EXPERIMENTATION 157, 157-60 (W. J. Whelan & Joan Morgan eds., 1979).

[289] Fredrickson, supra note 295, at __. *See* NIH Guidelines for Research Involving Recombinant DNA Molecules, 41 FED. REG. 27,902-27,943 (1976).

[290] *See* STAFF OF SUBCOMM. ON INVESTIGATIONS AND OVERSIGHT OF THE HOUSE COMM. ON SCI. & TECH., 98TH CONG., REPORT ON THE ENVIRONMENTAL IMPLICATIONS OF GENETIC ENGINEERING 10 (Comm. Print 1984).

[291] Fredrickson, *supra* note 295, at 153; Stetten, *supra* note 296, at 159.

risks. Its main purpose was to buy time to assess risks and develop risk-management practices. Despite intense incentives to proceed with research, and disagreement over the need for the moratorium, all researchers complied.[292] Researchers clearly had interests in proactively managing risks to forestall others imposing less apt or more burdensome restrictions,[293] but their response also reflected precaution in the face of uncertain and potentially severe consequences.[294] Despite significant disagreement over relaxing the moratorium, it became clear within a few years that risks were less severe than feared, and the initial guidelines could be relaxed. Subsequent experience, now based on millions of experiments, continues to confirm that view; rDNA laboratory research has not resulted in any hazardous incident.[295]

2. Fetal Research

Stem cells derived from human embryos hold great value for research and medical treatment, because they can develop into any cell type.[296] Researchers can collect human embryonic stem cells (hESCs) from embryos left over from *in vitro* fertilization (IVF), or through cloning.[297] Because extracting stem cells usually destroys the embryo, hESC research raises moral controversy. A majority of the U.S. public supports hESC research,[298] but some groups, including the Catholic Church, judge the destruction of human embryos an assault on the sanctity of life.[299]

In the controversy following U.S. legalization of abortion in 1973,[300] one widespread worry was expanded research using aborted fetuses.[301] In

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[292] Paul Berg, *Reflections on Asilomar 2 at Asilomar 3: Twenty-five Years Later*, 44 PERSPECTIVES IN BIO. & MED. 183, 184 (2001).

[293] *Id.*

[294] *Accord* Fredrickson, *supra* note 295, at 156.

[295] *See* Paul Berg, *Asilomar and Recombinant DNA*, NOBELPRIZE.ORG (2004), http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1980/berg-article.html.

[296] *Embryo* is the term for a fertilized egg from conception through approximately eight weeks of development, after which it becomes a *fetus*. *See generally* James A. Thomson et al., *Embryonic Stem Cell Lines Derived from Human Blastocysts*, 282 SCI. 1145 (1998); J.C. Mountford, *Human Embryonic Stem Cells: Origins, Characteristics and Potential for Regenerative Therapy*, 18 TRANSFUS MED 1, __ (2008).

[297] Mountford, *supra* note 304, at 3-4.

[298] GALLUP, Stem Cell Research (2015), *available at* http://www.gallup.com/poll/21676/stem-cell-research.aspx.

[299] *See, e.g.*, CONGREGATION FOR THE DOCTRINE OF THE FAITH, INSTRUCTION DIGNITAS PERSONAE ON CERTAIN BIOETHICAL QUESTIONS (2008).

[300] *See* Roe v. Wade, 410 U.S. 113 (1973).

[301] John C. Fletcher, *The Stem Cell Debate in Historical Context, in* THE HUMAN EMBRYONIC STEM CELL DEBATE 27, 27 (Suzanne Holland, ed., 2001).

response, the U.S. Department of Health, Education, and Welfare (now the Department of Health and Human Services (DHHS)), suspended funding for research on living embryos or fetuses.[302] In 1974, Congress formalized the suspension into a four-month moratorium, pending advice from the National Commission for the Protection of Human Subjects.[303] Based on the Commission's recommendations, DHHS enacted regulations for embryonic research in 1975 and lifted the moratorium – but with a catch.[304] The regulations required review of proposals by the NIH Ethics Advisory Board (EAB),[305] but the EAB charter and funding expired in 1980 and were never renewed.

In 1985, Congress replaced this *de facto* moratorium with a legal prohibition.[306] This new prohibition lasted until 1993, when President Clinton persuaded Congress to lift it.[307] After Republicans took control in 1995, Congress re-suspended funding of research in which an embryo is "destroyed, discarded, or knowingly subjected to risk of injury or death greater than that allowed for research on fetuses in utero," via a budget amendment—the Dickey-Wicker Amendment.[308] Congress has attached a version of this amendment to every DHHS appropriations bill since, thereby continually renewing the funding prohibition.[309]

Meanwhile, rapid growth of IVF techniques and scientific progress—including the first isolation of hESCs in 1998[310]—raised demands for federal funding. The language of the amendment gave room for President George W. Bush to allow federal funding for research on preexisting hESC lines[311] and cells derived without harming an embryo,[312] while maintaining

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[302] *Id.*

[303] *See* National Research Act, Pub. L. No. 93–34888, 88 Stat. 342 (1974).

[304] D.C. Wertz, *Embryo and Stem Cell Research in the United States: History and Politics*, 9 GENE THERAPY 674, 674 (2002). *See* 45 C.F.R. pt. 46.

[305] 45 C.F.R. § 46.204(d).

[306] *See* Health Research Extension Act of 1985, Pub. L. No. 99-158, § 498, 99 Stat. 820 (1985); COOK-DEEGAN, *supra* note 99, at 10.

[307] *See* National Institutes of Health Revitalization Act of 1993, Pub. L. No 103-43, § 121(c), 107 Stat. 122 (1993). *See also* 58 FED. REG. 7457 (Jan. 22, 1993).

[308] *See* Balanced Budget Down-payment Act, Pub. L. No 104-99, § 128, 110 Stat. 26 (1996); Fletcher, *supra* note 309, at 30-31.

[309] *See* 42 U.S.C. § 289g.

[310] Michael Shamblott et al., *Derivation of Pluripotent Stem Cells from Cultured Human Primordial Germ Cells*, 95 PROCEEDINGS NAT'L ACAD. SCI. 13726 (1998); Thomson et al., *supra* note 304.

[311] *See* Varnee Murugan, *Embryonic Stem Cell Research: A Decade of Debate from Bush to Obama*, 82 YALE J. BIOLOGY & MED. 101, 101 (2009).

[312] Exec. Order No. 13,435 (June 20, 2007).

the prohibition for newly created hESC lines.[313] President Obama expanded federal funding to new lines in 2009. Federal funding guidelines now allow research on cell lines from donated IVF embryos, subject to strict informed consent requirements,[314] but the Dickey-Wicker Amendment remains in place.[315]

The setbacks to hESC research have been substantial, particularly for early-stage research that may have high scientific value but is too remote from clinical or commercial application to attract private funding.[316] The moratoria and prohibitions forced researchers to choose between abandoning high-promise research, re-locating somewhere with fewer funding restrictions, or engaging in practices of uncertain legality.[317] Yet it was obvious that federal funding restrictions could not pretend to stop all hESC research, since state and privately funded research continued throughout.[318] The moratoria thus depended on categorical distinctions that were artificial, cumbersome, and of suspect moral validity.

3. Human Cloning

The theoretical possibility of cloning animals, including humans, has been recognized since the early 20th Century.[319] A key advance occurred in 1996, when a Scottish team cloned Dolly the sheep through somatic-cell nuclear transfer (SCNT), the transfer of the nucleus from a somatic (body) cell into an egg cell stripped of its nucleus. Dolly was the first mammal successfully cloned from an adult cell.[320] Within two weeks of the Dolly

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[313] *See* NAT'L INST. HEALTH, *Human Embryonic Stem Cell Policy Under Former President Bush (Aug. 9, 2001-Mar. 9, 2009)* (2015), http://stemcells.nih.gov/policy/pages/2001policy.aspx.

[314] *See* Exec. Order No. 13,505 (Mar. 9, 2009); National Institutes of Health Guidelines for Human Stem Cell Research, 74 FED. REG. 32170-02 (July 7, 2009).

[315] *See* Sherley v. Sebelius, 689 F.3d 776 (D.C. Cir. 2012), *cert. denied*, 133 S. Ct. 847 (2013).

[316] *See* Murugan, *supra* note 319; Debora Spar & Anna Harrington, *Selling Stem Cell Science: How Markets Drive Law Along the Technological Frontier*, 33 AM. J.L. & MED. 541, 541 (2007).

[317] Aaron D. Levine, *Policy Uncertainty and the Conduct of Stem Cell Research*, 8 CELL STEM CELL 132, 132-33 (2011).

[318] *See* Spar & Harrington, *supra* note 324, at 560-64.

[319] *See* Edward M. De Robertis, *Spemann's Organizer and Self-Regulation in Amphibian Embryos*, 7 NATURE REVIEW: MOLECULAR CELL BIOLOGY 296 (2006). For a general description of cloning, see PRESIDENT'S COUNCIL ON BIOETHICS, HUMAN CLONING AND HUMAN DIGNITY: AN ETHICAL INQUIRY xxiv (2002), *available at* http://hdl.handle.net/10822/559368.

[320] *See* Ian Wilmut et al., *Viable Offspring Derived from Fetal and Adult Mammalian Cells*, 385 NATURE 810 (1997).

announcement, researchers in Oregon announced the first primate cloning.[321]

The implications of these advances were vast, as was the potential for controversy. Cloning human cells and genes promised great scientific and therapeutic benefits,[322] but human reproductive cloning raised strong objections. Some objections concerned risks to clones, based on signs they might be at risk of deformities or premature aging.[323] Others concerned the morality of cloning and its potential uses, e.g., creating people with preselected traits, creating people for instrumental purposes, or the prospect of repugnant societies based on genetic manipulation, such as portrayed in Huxley's dystopic 1931 novel, BRAVE NEW WORLD.[324] As the President's Council on Bioethics summarized,

> [P]eople do not regard this as just another new technology. . . . The notion of cloning raises issues about identity and individuality, . . . the difference between procreation and manufacture, and the relationship between the generations. It also raises new questions about . . . the freedom and value of biomedical inquiry, our obligation to heal the sick . . . , and protection owed to nascent human life.[325]

Although the ability to clone humans was still some distance away, its evident ethical problems and fears of misuse prompted federal action. Ten days after the Dolly announcement, President Clinton ordered that "no federal funds shall be allocated for the cloning of human beings."[326] Clinton also called on the newly formed National Bioethics Advisory Commission (NBAC) to examine within ninety days the moral and legal implications of human cloning,[327] and asked privately funded researchers to adopt a voluntary moratorium "until [the NBAC] and our entire Nation have had a real chance to understand and debate the profound ethical implications of the latest advances."[328] The Biotechnology Industry Organization immediately

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[321] *See* Li Meng et al., *Rhesus Monkeys Produced by Nuclear Transfer*, 57 BIOLOGY OF REPROD. 454 (1997).

[322] NAT'L BIOETHICS ADVISORY COMM., CLONING HUMAN BEINGS: REPORT AND RECOMMENDATIONS OF THE NBAC 24-33 (1997) [hereinafter NBAC REPORT].

[323] *See* Terence Monmaney, *Prospect of Human Cloning Gives Birth to Volatile Issues*, L.A. TIMES, Mar. 2, 1997, at A1.

[324] ALDOUS HUXLEY, BRAVE NEW WORLD (1931). *See* NBAC REPORT, *supra* note 330, at 2-4.

[325] PRESIDENT'S COUNCIL ON BIOETHICS, *supra* note 327, at xxii.

[326] *Memorandum on the Prohibition on Federal Funding for Cloning of Human Beings,* 33 WKLY. COMP. PRES. DOC. 281 (1997).

[327] Letter from William J. Clinton to Harold Shapiro, Chair, Nat'l Bioethics Advisory Comm'n (Feb. 24, 1997), *reprinted in* NBAC REPORT, *supra* note 330.

[328] *Remarks Announcing the Prohibition on Federal Funding for Cloning of Human Beings and an Exchange with Reporters*, 33 WKLY. COMP. PRES. DOC. 278-79 (1997).

announced a moratorium on human cloning pending the NBAC review, while also declaring that "research involving duplication of cellular material has . . . enormous potential benefits for society," and urging Clinton to oppose "any hastily drafted laws . . . that may, however well intentioned, inadvertently also ban this valuable research."[329]

Given its tight deadline, the NBAC focused narrowly on cloning to create a child via SCNT[330] and concluded that human reproductive cloning "is morally unacceptable."[331] The Commission had difficulty reaching agreement on ethical issues, however, so its reasoning for this conclusion relied prominently on health risks to the cloned embryo or child, although also mentioning other concerns.[332] They recommended maintaining the federal funding and voluntary private moratoria, and also enacting legislation to formalize a comprehensive three- to five-year moratorium. They cautioned that legislation should be drafted narrowly, to avoid stifling valuable research that does not pose the same risks.[333] President Clinton subsequently proposed legislation to enact a five-year moratorium on human cloning by SCNT.[334] Multiple scientific societies adopted voluntary five-year moratoria with the same scope,[335] while other bills to restrict cloning flooded Congress and state legislatures.[336]

Pressure for federal action rose in 1998, following one scientist's provocative announcement that he intended to clone humans before Congress prohibited it.[337] The Food and Drug Administration (FDA) responded by announcing it had jurisdiction over human cloning, so any experiment conducted without its approval would be illegal.[338] FDA control was insuffi-

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[329] *See, e.g.*, Letter from Henri A. Termeer, Chairman & Charl B. Fedlbaum, President, Biotechnology Industry Org., to William J. Clinton.(Mar. 27, 1997), *available at* https://www.bio.org/advocacy/letters/support-voluntary-moratorium.

[330] NBAC REPORT, *supra* note 330, at 3-4.

[331] *Id.* at iii.

[332] *See id.* at 107-08; Gina Kolata, *Clinton's Advisory Panel Backs Moratorium on Human Clones*, N.Y. TIMES, May 18, 1907.

[333] NBAC REPORT, *supra* note 330, at 109.

[334] *Draft Legislation Entitled the "Cloning Prohibition Act of 1997," Message from the President of the United States*, H. Doc. 105-97, 105th Cong. (1997).

[335] *See* 144 CONG. REC. 943 (daily ed. Feb. 5, 1998); Meredith Wadman, *US Biologist Adopt Cloning Moratorium*, 389 NATURE 319 (1997).

[336] *See* Lori B. Andrews, *Is There a Right to Clone? Constitutional Challenges to Bans on Human Cloning*, 11 HARV. J. L. & TECH. 643, 645 & tbls. 1-2 (1998).

[337] ANDREA L. BONNICKSEN, CRAFTING A CLONING POLICY: FROM DOLLY TO STEM CELLS 55-56 (2002).

[338] *See* Dr. Stuart Nightingale, Dear Colleague Letter, Oct. 26, 1998, *available at* http://www.fda.gov/oc/oha/irbletr.html. No one has challenged FDA's jurisdictional claim. *See generally* Richard A. Merrill & Bryan J. Rose, *FDA Regulation of Human*

cient to calm concern about rogue scientists, however, and federal lawmakers proposed several new bills, including one, S. 1601, that criminalized any use of SCNT to create human embryos.[339] This broad scope alarmed researchers that over-inclusive legislation might unnecessarily prohibit valuable research. Drug companies, medical organizations, and research groups mobilized against S. 1601 and other "poorly crafted legislation,"[340] arguing that FDA jurisdiction and voluntary moratoria gave enough protection and were preferable to federal regulation.[341] The campaign culminated in a successful filibuster of S. 1601, and no other cloning law came to a vote that session.

There have since been multiple unsuccessful attempts to pass federal legislation restricting cloning,[342] as well as failed attempts to promote an international convention on cloning.[343] Restrictions or prohibitions on cloning are in place in multiple U.S. states and countries,[344] but scientific advances have developed new techniques that fall outside the scope of narrowly or inaptly drafted laws, allowing technologies to keep progressing.[345]

In this case, voluntary moratoria on the riskiest, most controversial application of a new technology helped calm public fear and forestall restrictive regulation. But while ethical concerns drove calls for moratoria, achieving clarity and agreement how to apply ethical principles in regulations has been difficult, leading to a persistent focus on concrete risks that are likely to decline with scientific progress. The case illustrates the challenge of defining the scope of technology controls under rapid progress, and suggests a general dilemma in design of moratorium: they face dual risks, of being overbroad and unnecessarily restricting high-value research, or over-

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Cloning: Usurpation or Statesmanship?, 15 HARV. J.L. & TECH. 85 (2011).

[339] *Human Cloning Prohibition* Act, S. 1601, 105th Cong. (1998).

[340] 144 CONG. REC. S322-23 (daily ed. Feb. 3, 1998).

[341] *See* BONNICKSEN, *supra* note 346, at 61. *See, e.g.*, David Korn, ASSOC. AM. MED. COLLEGES, Statement on Cloning: Legal, Medical, Ethical, and Social Issues, Testimony before the Subcomm. on Health & Env't, H. Comm. on Commerce (Feb. 12, 1998); *AMA Seeks 5-Year Cloning Moratorium*, L.A. TIMES, Feb. 13, 1998.

[342] *See, e.g.*, H.R. 2505, 107th Cong. (2001); H.R. 534, 108th Cong. (2003); S. 303, 108th Cong. (2003); S. 658, 109th Cong. (2005).

[343] *See* U.N. AD HOC COMM. ON AN INT'L CONVENTION AGAINST THE REPRODUCTIVE CLONING OF HUMAN BEINGS (2015), http://legal.un.org/cloning/. *See also* G.A. Res. 59-280, U.N. Doc. A/Res/59/280 (Mar. 23, 2005).

[344] *See* Additional Protocol to the Convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine, on the Prohibition of Cloning Human Beings, Dec. 1, 1998, 2177 U.N.T.S. 366; Russell Korobkin, *Stem Cell Research and the Cloning Wars*, 18 STAN. L. & POL'Y REV. 169 (2007).

[345] *See* Andrews, *supra* note 336, at 660-61.

specific and thus only effective in the short term, eroding over time to a symbolic commitment and a bureaucratic burden of little real effect.

4. Viral Gain-of-Function Research

In 2011, influenza researchers in Wisconsin and the Netherlands sparked global controversy by announcing they had modified the highly pathogenic avian flu virus H5N1 to be transmissible between mammals.[346] The modified virus, if released, is potentially able to trigger a global pandemic.[347] These "gain-of-function" studies were so alarming that U.S. and Dutch regulators initially tried to limit publication,[348] although both were subsequently published in March 2012.[349] Some scientists and citizens argued against publication based on risks the modified virus would be used for biological warfare or terrorism, while others judged the risk of release so great the research should not be done at all.[350] Influenza researchers responded that they were adequately managing the risks and the research was essential to understand how to prevent and respond to future outbreaks.[351]

In response to mounting scientific and public criticism, thirty-nine leading influenza researchers announced a voluntary sixty-day moratorium on H5N1 gain-of-function research in January 2012. The stated purpose of the moratorium was:

> to provide time to explain the public health benefits of this work, to describe the measures in place to minimize possible risks, and to enable or-

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[346] David Malakoff, *Proposed H5N1 Research Reviews Raise Concern*, 338 SCIENCE 1271, 1271 (2012).

[347] A FRAMEWORK FOR GUIDING U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES FUNDING DECISIONS ABOUT RESEARCH PROPOSALS WITH THE POTENTIAL FOR GENERATING HIGHLY PATHOGENIC AVIAN INFLUENZA H5N1 VIRUSES THAT ARE TRANSMISSIBLE AMONG MAMMALS BY RESPIRATORY DROPLETS 1 (2013), *available at* http://www.phe.gov/s3/dualuse/Documents/funding-hpai-h5n1.pdf [hereinafter U.S. FUNDING FRAMEWORK].

[348] *See* A. Casadevall & T. Shenk, *The H5N1 Manuscript Redaction Controversy*, Editorial, 3 MBIO e00022–12 (2012); Declan Butler, *Court Upholds Need for Export Permits for Risky Flu Research*, NATURE NEWS BLOG (Sept. 26, 2013, 7:10 PM), http://blogs.nature.com/news/2013/09/court-upholds-need-for-export-permits-for-risky-flu-research.html.

[349] *See* Sander Herfst et al., *Airborne Transmission of Influenza A/H5N1 Virus Between Ferrets*, 336 SCI. 1534 (2012); Masaki Imai et al., *Experimental Adaptation of an Influenza H5 HA Confers Respiratory Droplet Transmission to a Reassortant H5 HA/H1N1 Virus in Ferrets*, 486 NATURE 420 (2012).

[350] Denise Grady & Donald G. McNeil Jr., *Debate Persists on Deadly Flu Made Airborne*, N.Y. TIMES, Dec. 26, 2011, at A1.

[351] Ron A. M. Fouchier et al., *Transmission Studies Resume for Avian Flu*, Letters, 339 SCI. 520, 520 (2013).

> ganizations and governments around the world to review their policies . . . regarding these experiments.[352]

As controversy persisted, the researchers announced an indefinite extension to the voluntary moratorium in March 2012.[353] One participant described the moratorium as a reaction to "horror that scientists were brewing up deadly diseases. It became clear that the public needed reassurance and justification about these experiments."[354]

Through 2012, researchers and regulators discussed safety practices and the benefits and risks of the research at several meetings, including a two-day international workshop at NIH in December,[355] while several countries and the World Health Organization worked on new research guidelines.[356]

In February 2013, the researchers who adopted the moratorium announced they would resume research in countries that had approved guidelines,[357] but controversy persisted.[358] The risk assessment called for by NIH had not been completed,[359] nor had most jurisdictions (including the United States) adopted specific regulations or guidelines for research safety. Moreover, it was widely perceived that the debate had been dominated by a small circle of insiders. As one critic wrote in a NATURE commentary, "Rather than use the avian flu moratorium to seek advice, listen and foster debate, many influenza scientists engaged in an academic exercise of self-justification."[360] At the only meeting to engage broader participation, a past president of the Royal Society stated that, "on the balance of probabilities,

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[352] Fouchier et al., *supra* note 360.

[353] David Malakoff, *H5N1 Researchers Announce End of Research Moratorium*, SCIENCE, Jan. 23, 2013, http://news.sciencemag.org/scienceinsider/2013/01/h5n1-researchers-announce-end-of.html.

[354] *Id*.

[355] Fouchier et al., *supra* note 360. *See* NAT'L INST. OF HEALTH, *Gain-Of-Function Research on Highly Pathogenic Avian Influenza H5N1 Viruses: An International Consultative Workshop*, http://osp.od.nih.gov/office-biotechnology-activities/event/2014/gain-function-research-highly-pathogenic-avian-influenza-h5n1-viruses-international-consultative (last visited Nov. 25, 2015).

[356] *See, e.g.*, WORLD HEALTH ORG., GUIDANCE FOR ADOPTION OF APPROPRIATE RISK CONTROL MEASURES TO CONDUCT SAFE RESEARCH ON H5N1 TRANSMISSION (2012) (proposing laboratory safety guidelines for H5N1 research); U.S. FUNDING FRAMEWORK, *supra* note 356.

[357] Fouchier et al., *supra* note 360 (announcing the conclusion of the voluntary moratorium).

[358] *See* Connor, *supra* note 361; Declan Butler, *Work Resumes on Lethal Flu Strains*, NATURE, Jan. 23, 2013, http://www.nature.com/news/work-resumes-on-lethal-flu-strains-1.12266 (last visited May 22, 2014).

[359] *Vigilance Needed*, Editorial, 493 NATURE 451, 452 (2013).

[360] Simon Wain-Hobson, *H5N1 Viral-Engineering Dangers Will Not Go Away*, Commentary, 495 NATURE 411, 411 (2013).

going ahead and lifting the moratorium is more dangerous than not going ahead."[361]

Concern grew further in 2014, following several biosafety lapses at supposedly secure U.S. federal labs.[362] In response, in October 2014 the Obama Administration announced a new moratorium on federal funding of gain-of-function studies on influenza and the respiratory viruses MERS and SARS "until a robust and broad deliberative process is completed that results in the adoption of a new [federal] gain-of-function research policy."[363] The administration also requested voluntary stoppage of privately funded studies pending completion of a risk assessment by the National Science Advisory Board for Biosecurity (NSABB) and National Research Council (NRC).[364] It is expected that when this assessment and development of new controls are completed (estimated to take one year), the moratorium will be lifted.[365] This new moratorium has affected only about two-dozen experiments,[366] but remains controversial.[367] Some researchers claim it jeopardizes routine studies needed to design and test seasonal influenza vaccines and hinders efforts to stem the ongoing MERS epidemic. Others express broader objections to government interference with research.[368]

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[361] *See* Connor, *supra* note 361.

[362] Jocelyn Kaiser, *Lab Incidents Lead to Safety Crackdown at CDC*, SCIENCE, July 11, 2014, http://news.sciencemag.org/biology/2014/07/lab-incidents-lead-safety-crackdown-cdc.

[363] U.S. GOVERNMENT GAIN-OF-FUNCTION DELIBERATIVE PROCESS AND RESEARCH FUNDING PAUSE ON SELECTED GAIN-OF-FUNCTION RESEARCH INVOLVING INFLUENZA, MERS, AND SARS VIRUSES 1 (2014), *available at* http://www.phe.gov/s3/dualuse/Documents/gain-of-function.pdf [hereinafter FUNDING PAUSE]. *See also* FRANCIS S. COLLINS, STATEMENT ON FUNDING PAUSE ON CERTAIN TYPES OF GAIN-OF-FUNCTION RESEARCH (2014), *available at* www.nih.gov/about/director/10172014_statement_gof.htm.

[364] FUNDING PAUSE, *supra* note 373, at 1.

[365] U.S. GOVERNMENT GAIN-OF-FUNCTION DELIBERATIVE PROCESS AND RESEARCH FUNDING PAUSE ON SELECTED GAIN-OF-FUNCTION RESEARCH INVOLVING INFLUENZA, MERS, AND SARS VIRUSES, FREQUENTLY ASKED QUESTIONS 4 (2014), *available at* http://www.phe.gov/s3/dualuse/Documents/gof-qanda.pdf.

[366] *Id.*

[367] *Compare, e.g.*, Marc Lipstich & Thomas V. Inglesby, Editorial, *Moratorium on Research Intended to Create Novel Potential Pandemic Pathogens*, 5 MBIO 1 (2014), http://mbio.asm.org/content/5/6/e02366-14.full.pdf+html, *with* Michael J. Imperiale & Arturo Casadevall, Editorial, *Vagueness and Costs of the Pause on Gain-of-Function (GOF) Experiments on Pathogens with Pandemic Potential, Including Influenza Virus*, 5 MBIO 1 (2014), http://mbio.asm.org/content/5/6/e02292-14.full.pdf+html.

[368] *See* Sara Reardon, *Viral-Research Moratorium Called Too Broad*, NATURE, Oct. 23, 2014, http://www.nature.com/news/viral-research-moratorium-called-too-broad-1.16211; Jocelyn Kaiser, *Researchers Rail Against Moratorium on Risky Virus Exper-*

Here, as with rDNA research, the initial moratorium was motivated by concerns about both direct and indirect risks of research, and adopted voluntarily by scientists. In this case, however, there were stronger concerns about researchers' willingness to subject safety practices to outside scrutiny. Researchers' statements suggested they viewed the main problem as unfounded fear, and the voluntary moratorium as a tactic to instruct the public and officials while keeping control internal. It failed in that aim, as widespread perception of inadequate consultation and widely reported biosecurity lapses inflamed controversy and prompted the broader federal moratorium. In both the rDNA and viral-research cases, safety protocols developed under the moratoria did not address indirect risks related to how the research could be used, such as intentionally creating dangerous viruses. Even critics of the decision to resume research express perhaps excessive confidence in quantitative risk assessment, given the potential importance of hard to quantify risks related to lapses in safety performance or intentional misuse.[369]

5. E.U. Genetically Modified Crop Authorizations

Crops with genetic modifications for desired traits such as pest resistance, improved nutrition, and reduced spoilage were developed in the 1980s, and widely marketed by the late 1990s.[370] Genetically modified (GM) varieties now make up most U.S. planting of several major crops,[371] and smaller but substantial fractions worldwide.[372] Multiple scientific reviews have concluded that the health and environmental risks of GM crops are similar to those of conventional crops.[373] Yet GM crops have faced per-

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iments, SCIENCE, Oct. 22, 2014, http://news.sciencemag.org/biology/2014/10/researchers-rail-against-moratorium-risky-virus-experiments.

369 *See generally, e.g.*, W. Paul Duprex et al., *Gain-of-Function Experiments: Time for a Real Debate*, 13 NATURE REV. MICROBIOLOGY 58 (2015).

370 *See* PEW INITIATIVE ON FOOD & BIOTECHNOLOGY [PIFB], ISSUES IN THE REGULATION OF GENETICALLY ENGINEERED PLANTS AND ANIMALS 1 (2004); ROBERT L. PAARLBERT, THE POLITICS OF PRECAUTION: GENETICALLY MODIFIED CROPS IN DEVELOPING COUNTRIES 2-3 (2001).

371 ECON. RESEARCH SERV., U.S. DEPT. AGRICULTURE, GENETICALLY ENGINEERED VARIETIES OF CORN, UPLAND COTTON, AND SOYBEANS IN THE UNITED STATES, 2000-15 (2015), *available at* http://ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx.

372 JAMES CLIVE, GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS: 2014, ISAAA Brief No. 49, 1-2, 5, fig.1 (2014).

373 *See, e.g.*, COMM. ON IDENTIFYING & ASSESSING UNINTENDED EFFECTS OF GENETICALLY ENGINEERED FOODS ON HUMAN HEALTH, INST. OF MED. & NAT'L RESEARCH COUNCIL, SAFETY OF GENETICALLY ENGINEERED FOODS 8 (2004); COMM. ON ENVTL.

sistent concerns about risks such as biodiversity reduction, pesticide resistance, and ecosystem disruption.[374] Additional, more politically inflected concerns include the prospect of GMOs exacerbating North-South power disparities, or that industry-captured regulators will not adequately control GMO-related risks.[375]

Based on such concerns, several environmental groups campaigned in the 1980s and 1990s for a worldwide moratorium on environmental release of GMOs pending adoption of an international treaty regulating their use.[376] Opposition was especially strong in Europe, where the Green Party held political influence and the early 1990s "Mad Cow" crisis had reduced public trust in the food industry.[377] By the late 1990s, majorities in multiple European countries disapproved of GMO development,[378] and vandalism repeatedly disrupted field trials.[379]

At the E.U. level, dispute focused on licensing GM crops for planting or import as food or animal feed. Under a 1990 Directive, licensing a new crop required an environmental risk assessment, approval by the European Commission and Council, and review in the country first proposed for marketing the new variety.[380] The Directive included a safeguard clause that let each member state block a variety in their territory even after E.U. approval, based on "justifiable" concern it "constitutes a risk to human health or the

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IMPACTS ASSOCIATED WITH COMMERCIALIZATION OF TRANSGENIC PLANTS, BD. ON AG. & NATURAL RESOURCES, NAT'L RESEARCH COUNCIL, ENVIRONMENTAL EFFECTS OF TRANSGENIC PLANTS: THE SCOPE AND ADEQUACY OF REGULATION 5 (2002) [hereinafter NRC TRANSGENIC PLANTS REPORT].

[374] *See generally, e.g.*, Statement of Policy: Foods Derived From New Plant Varieties, 57 FED. REG. 22,984 (1992); NRC TRANSGENIC PLANTS REPORT, *supra* note 383, NAT'L RESEARCH COUNCIL, GENETICALLY MODIFIED PEST-PROTECTED PLANTS: SCIENCE AND REGULATION (2000); Anthony J. Connor & Jeanne M.E. Jacobs, *Food Risks from Transgenic Crops in Perspective*, 16 NUTRITION 709 (2000).

[375] PETER PRINGLE, FOOD, INC.: MENDEL TO MONSANTO—THE PROMISES AND PERILS OF THE BIOTECH HARVEST 101-02 (2003).

[376] *See* NGO Call for a Legally Binding Protocol on Biosafety, *opened for signature* Dec. 10, 1994.

[377] Sarah Lieberman & Tim Gray, *The So-Called 'Moratorium' on the Licensing of New Genetically Modified (GM) Products by the European Union 1998-2004: A Study in Ambiguity*, 15 ENVTL. POL. 591, 595 (2006); PRINGLE, *supra* note 385, at 101-04.

[378] Thomas J. Hoban, *Public Attitudes Towards Agricultural Biotechnology*, 4, 13, fig.6 (U.N. Food & Ag. Org., ESA Working Paper No. 04-09, 2004).

[379] *See generally* Marcel Kuntz, *Destruction of Public and Governmental Experiments of GMO in Europe*, 3 GM CROPS & FOOD 258 (2012).

[380] Council Directive 90/220, art. 16, 1990 O.J. (L 117), 15 (EC). *See generally* Rene von Schomberg, AN APPRAISAL OF THE WORKING IN PRACTICE OF DIRECTIVE 90/220/EEC ON THE DELIBERATE RELEASE OF GENETICALLY MODIFIED ORGANISMS (1998).

environment."[381] In operation, this approval process was quite precautionary; although the European Food Safety Authority (EFSA) consistently found GM crops safe and recommended approval, the Commission authorized only two over eight years. Even these approvals met strong opposition, from the European Parliament and some member states.[382]

It was clear by the late 1990s that the Directive needed revision.[383] In 1999, twelve member states—enough to block the qualified majority needed to approve licensing at the Council—announced plans to suspend further GMO authorizations pending stricter regulations for risk assessment, traceability, and labeling.[384] Several states also used the safeguard clause or other means to block national authorization.[385] Although this period is widely considered a *de facto* moratorium on GMO authorizations,[386] the official E.U. position is that there was never a moratorium—merely the "reasonable attitude of a prudent government . . . faced with scientific complexity and uncertainty" in the "normal process of assessment."[387]

New regulations enacted in 2001 and 2003 did not end internal conflict, but added procedures to surmount deadlocks.[388] The first E.U. approval under the new procedures occurred in April 2004 and others have trickled through since, although nine states still block GMO cultivation in their territory.[389] Late 2014 saw hints of a compromise, with acceptance of continued

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381 Council Directive 90/220, *supra* note 390, at art. 16.

382 *See* LES LEVIDOW & SUSAN CARR, GM FOOD ON TRIAL: TESTING EUROPEAN DEMOCRACY 137-40, 146, 153, 169, 235-44 (2010); DIAHANNA LYNCH & DAVID VOGEL, THE REGULATION OF GMOS IN EUROPE AND THE UNITED STATES: A CASE-STUDY OF CONTEMPORARY EUROPEAN REGULATORY POLITICS (2001), http://www.cfr.org/agricultural-policy/regulation-gmos-europe-united-states-case-study-contemporary-european-regulatory-politics/p8688.

383 *See Report on the Review of Directive 90/220/EC in the Context of the Commission's Communication on Biotechnology and the White Paper*, at 10, COM (96) 630 final (Dec. 10, 1996).

384 Press Release, Eur. Comm'n, 2194th Council Meeting – Environment – Luxembourg, 24/25 June 1999 (June 25, 1999), *available at* http://europa.eu/rapid/press-release_PRES-99-203_en.htm?locale=en.

385 Panel Report, *European Communities – Measures Affecting the Approval and Marketing of Biotech Products*, WT/DS291/R, ¶¶ 4.150, 4.153, 4.203 (Sept. 29, 2006).

386 *Accord id.*; Lieberman & Gray, *supra* note 387.

387 *See* First Oral Statement of the European Communities, *European Communities – Measures Affecting the Approval and Marketing of Biotech Products*, WT/DS291/R (Sept. 29, 2006) ¶¶ 4.500-4.525.

388 *See* Council Directive 2001/18, 2001 O.J. (L 106) 1 (EC); Council Regulation 1829/2003, 2003 O.J. (L 268) 1 (EC) at arts. 19, 35.

389 *See* Council Directive 2001/18, *supra* note 393, at art. 23; Memorandum from the Eur. Comm'n, Questions and Answers on EU's Policies on Cultivation and Imports of GMOs (Nov. 6, 2013), *available at* http://europa.eu/rapid/press-release_MEMO-13-

national bans in return for further easing of E.U.-wide approvals.[390]

This case pitted pro-GMO economic interests of large agricultural firms and exporting nations against anti-GMO economic interests of some E.U. farmers plus a set of expansive risk concerns based on a mix of generalized anxiety about new technologies, distrust of agribusiness, and moral principles.[391] Given intractable intra-E.U. conflict, the *de facto* moratorium may have served aggregate E.U. interests better than available alternatives,[392] while also representing a multi-year victory for opponents. The moratorium did not help reduce conflict by clarifying and resolving risks, for several reasons: partly because concern over uncertain health and environmental risks was only one of several motivations for opposition, partly because GMO opponents distrusted the expert assessment body, and partly because it was never acknowledged as an intentional suspension to serve this purpose.[393] The moratorium may, however, have helped reduce conflict by a cruder mechanism: exhausting both sides to the point they were willing to retreat from absolutist positions. The recent proposal, which shows promise by virtue of being denounced by both sides, may represent a step in that direction.[394]

IV. A Framework for Analyzing Historical Moratoria

The cases above show that moratoria on similar subject matter can vary substantially in their context, intended purposes, and effects. In this part, we present a categorization of moratoria into three ideal types based on intended purpose. This categorization provides a more consistent basis to distinguish moratorium aims, the mechanisms by which they may provide benefits, and the conditions for them to do so, and thereby provides more useful guidance for crafting future moratoria. The types are:

> 1) *Risk-management moratoria*: moratoria proposed to enable risk assessment, regulation, and management for activities that may pose serious and imperfectly understood health or environmental risks;

952_en.htm.

[390] *See* Daniel Cressey, *Compromise Blooms in European GM Crop Debate*, NATURE, Dec. 5, 2014, http://www.nature.com/news/compromise-blooms-in-european-gm-crop-debate-1.16503.

[391] *See* Lieberman & Gray, *supra* note 387, at 521-29, 596.

[392] *See id.* at 607.

[393] *See* FRIENDS OF THE EARTH, THROWING CAUTION TO THE WIND: A REVIEW OF THE EUROPEAN FOOD SAFETY AUTHORITY AND ITS WORK ON GENETICALLY MODIFIED FOODS AND CROPS (2004).

[394] *Cf. Room for Growth*, Editorial, 516 NATURE 143, 143 (2014).

2) *Principled-conflict moratoria*: moratoria proposed as landmarks in situations of intractable conflict over an activity that some parties judge wrong independent of its risks or other consequences;

3) *Bargaining moratoria:* moratoria proposed as bargaining tools to help reach agreement or resolve conflict in situations where parties have well understood material interests.

Categorizing moratoria by purpose presumes some degree of alignment among actors in the purposes they assign to the moratorium. A slim majority of our cases lie cleanly within one type, but cases can have elements of more than one type if a moratorium's purposes are ambiguous, vary among actors, change over time, or are misrepresented. The three types also vary in the subsequent processes that operate under the moratorium to promote more confident or less controversial subsequent decisions about the suspended activity. For each type, we discuss the circumstances in which moratoria are proposed, the moratoria's intended purposes, and the conditions for success at advancing those purposes. We then briefly discuss intermediate cases.

A. Risk-Management Moratoria

Risk-management moratoria are proposed when an activity is perceived to pose serious and imperfectly understood risks of harm, with the aim of enabling risk assessment and control. These cases share three basic characteristics. First, moratorium proponents perceive an activity to carry risks of harm (environmental, health, safety, economic, or social) that are potentially severe, weakly understood, and perhaps irreversible. Second, proponents judge these risks to be inadequately controlled, due to either lack of knowledge how to control them or lack of legal authority, effective regulatory mechanisms, or political support. Third, continuance of the activity is perceived to increase risks or undermine attempts to assess and control them, usually because the activity is expanding rapidly. Under such conditions, individual decisions to slow or stop the activity are ineffective: allowing time to assess risks and develop responses requires a collective suspension. Of our cases, the moratoria on rDNA and viral research fall cleanly into this type, while those on dumping, whaling, cloning, and GMOs are mixed cases partly of this type.

The activity targeted by a risk-management moratorium is often new, such as a new technology or area of scientific research, with weakly understood consequences. This is not necessary, however; it is also possible that advancing knowledge or rapid expansion can raise concern about a long-standing activity's risks (e.g., whaling), or that uncertainty about risks may persist a long time if relevant data and knowledge are weak (e.g., dumping).

If a moratorium is adopted for risk-management purposes, specific implications follow for its scope, actors, and termination conditions. Its scope must cover the risky activities of concern, yet not obstruct the research, assessment, or policy-development activities needed to assess risks and develop effective control measures.

The actors supporting or even initiating a risk-management moratorium can include insiders, parties engaging in the activity of concern. Insiders may support a moratorium because they share aims of rational risk management and limiting societal harms, and are willing to accept reasonable risk-related controls on the activity. Yet even if insiders are not mainly motivated by such public-interest concerns, or do not think prudent risk control requires a moratorium, they may still judge it in their collective interest to support one if they think outsiders are sufficiently alarmed. Supporting a moratorium can signal that insiders are concerned about risks and addressing them responsibly, provide time to educate policy-makers and calm public fears, and thus help insiders keep control and avoid more burdensome restrictions that might otherwise be imposed from outside without their participation.

Insiders may thus support a moratorium for diverse reasons, and, indeed, may disagree about the severity of risks, the need for a moratorium, and the justification for its subsequent removal or relaxation—as the rDNA and viral research cases variously illustrate.[395] Whatever the range of insiders' reasons for support, a voluntary moratorium can surmount the collective-action problem that obstructs individual efforts to slow or stop the activity, by coordinating choices and exerting normative pressure on those less inclined to join. Funding or regulatory authorities can further ease the collective-action problem by providing additional incentives or enforceable rules, or indeed may impose a moratorium even without insider support—e.g., if insiders disagree about the seriousness of risks, do not trust outsiders to regulate them sensibly, or cannot overcome their internal collective-action problems. Consequently, although our two clearest risk-management cases include insider support, we do not identify this as an essential condition of the type.

A moratorium is only the first step toward effectively managing risks. Other required elements include the assessment and regulatory development processes, plus subsequent decisions to resume, limit, or regulate the activity. A moratorium cannot be held responsible for all parts of effective risk

[395] *See* Lieberman, Gray & Groom, *supra* note 99, at 530.

control, but only for how it enables and contributes to this broader process. To this end, its termination conditions must be strict enough to engender confidence that it has allowed effective risk-assessment and regulatory processes to proceed, so subsequent decisions are perceived as prudent and legitimate.

The two cases that fall cleanly into this type illustrate the variation in outcomes possible among insider-led risk-management moratoria, one highly effective and one less so. In the rDNA research case, insiders strongly supported the proposed moratorium. Risk assessment and regulatory development advanced rapidly under the moratorium. Controls focused mainly on distinguishing experiments by expected risk and adapting well-known laboratory containment strategies, whose further development the moratorium did not hinder. The moratorium and new controls built sufficient support for partial resumption of the risky experiments, albeit over some dissent. The subsequent enforceable guidelines allowed research to flourish but were nonetheless conservative, allowing later relaxation with no mishaps. The viral research case provides the counter-example of a moratorium biased too strongly toward insider interests, with the accompanying risk assessment and controls viewed as so permissive that they increased outside concern and opposition (albeit together with widely publicized lab-safety failures). The resolution of the case, following imposition of a broader moratorium by federal funding agencies, is pending as we write.

B. Principled-Conflict Moratoria

These moratoria are proposed in the context of intractable conflict over an activity, whose opponents judge it wrong based on moral or ideological principles. Because principled opposition is not based on consequences that can be mitigated, opponents tend to judge risk assessment or regulation (short of a ban) to be inadequate or irrelevant. Principled opposition also tends to be categorical, in that opponents perceive no benefit in compromise but instead prefer to keep fighting for full resolution in their favor. While this type is defined by at least some of the contested activity's opponents acting from principled motives, supporters' motives can be variable, including opposing principles, advancing knowledge, or commercial interests. In our cases, this type applies clearly to fetal research and partly to dumping, whaling, cloning, and Antarctic mining. In these cases, at least some actors sought a moratorium because they judged the contested activity (using embryos, killing whales, disrupting the Antarctic environment for commerce, procreation through cloning) to be intrinsically wrong.

Given these cases' strong and persistent conflict, the purposes and effectiveness of a moratorium cannot be characterized in aggregate, but must be considered separately for opponents and supporters of the contested activity. A moratorium is a real but partial victory for principled opponents and a partial defeat for supporters—with the degree of victory and defeat related to the moratorium's scope, binding character, and termination conditions. Opponents would prefer a full ban, but presumably lack the support or authority needed to secure one. Given these limits, they may favor a moratorium because they see it as offering a ban in all but name,[396] or as a salient benchmark of success around which to rally supporters.[397] Alternatively, they may expect conditions to shift in their favor under the moratorium, due to shifts in external factors or their own continuing advocacy, so they are subsequently able to keep the moratorium indefinitely or harden it into a full prohibition.

The activities subject to a principled-conflict moratorium can be old or new—long-standing practices on which values have shifted (e.g., whaling and dumping), or new activities that threaten present moral values (e.g., stem cells and cloning)—but the impact and significance of a moratorium differs in the two cases. A moratorium on a long-practiced activity represents a major victory for opponents. It shifts the politics of the issue by changing the status quo, and may also shift political alignments by disrupting existing economic interests, as the dumping case illustrates. A moratorium on a new activity, in contrast, will be less disruptive of existing interests simply because these interests are newer and less established. Such a moratorium may also be less stable, because the nature of the contested activity, the basis for opposition, and the boundary between principled and risk concerns can be more ambiguous and labile under scientific and technological progress when the contested activity is new—as the cloning and fetal-research cases illustrate.

In seeking a moratorium rather than a ban, principled opponents aim to broaden support to include actors with other motivations, including risk-based concerns. As a result, principled-conflict moratoria may be accompanied by establishment of risk-assessment processes, even though these are unlikely to change the views of leading opponents. Any assessment process so created is awkwardly situated. It may be tasked with resolving questions that appear scientific in form but are practically unanswerable due to limits in knowledge, data, or observational capabilities.[398] Alternatively, it may be subverted, attacked, or ignored by some parties. Yet assessment processes can also wield more than expected influence, if the mix of actors' moti-

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[396] *See* COOK-DEEGAN, *supra* note 99, at 4.
[397] *See* Lieberman, Gray & Groom, *supra* note 99, at 530.
[398] *See generally* ALVIN WEINBERG, SCIENCE AND TRANS-SCIENCE (1973).

vations shifts toward concern about risks that can be informed by effective assessments. Variants of marginalized assessment processes can be found in the dumping and whaling cases. In the cloning case, an expert panel was given a broad charge including both health and bioethical risks, but framed its report mainly in terms of health risks to cloned people—oddly divergent from opponents' main objections. We expect pure principled-conflict moratoria to be uncommon, because the fact of adopting a moratorium (rather than a ban) will typically mean principled opponents had to recruit supporters with other motivations. In our cases, we identify the *de facto* moratorium in the fetal-research case as the only pure principled-conflict case, because only here was there no attempt to motivate opposition by claims of uncertain risks and no recourse to an expert assessment body.

In cases marked by substantial principled conflict, the purpose and effectiveness of a moratorium will be difficult to characterize in aggregate: any moratorium will benefit principled opponents of the contested activity, harm its supporters, and have ambiguous effect for parties motivated by risks who want to learn more about them. Specifics of moratorium design will be similarly contested, with opponents wanting broad scope and restrictive termination conditions, and supporters wanting the opposite. Our only general conjecture about characteristics of these moratoria is that insiders will never support such a moratorium: principled-conflict moratoria are imposed by a government or other outside authority, acting on outsiders' concerns.

There may be ways a principled-conflict moratorium can bring broader benefits, but these are quite limited. Absent the prospect of complete victory, the ambiguity a moratorium implies about the eventual fate of the contested activity may be tactically helpful to leaders on both sides in mobilizing supporters, letting them claim either constructive victory or continuing peril according to their needs, as in the whaling case. Alternatively, a moratorium may serve as a tacit agreement to restrain the most violent or aggressive tactics, or otherwise mute the intensity of a conflict that is costly for all.[399] The subsequent reduction in anti-GMO violence suggests the E.U. moratorium was effective in this regard, while continuing violent confrontations over whaling suggest the whaling moratorium is not. Finally, any moratorium, even in principled-conflict cases, may provide benefits by mere delay, allowing the passage of time or changes in external conditions to make the terms of the conflict less intractable, by reducing the value of the contested activity, shifting political alignments, or allowing scientific progress to move the activity into less morally contested space—as oc-

[399] Lieberman, Gray & Groom, *supra* note 99, at 519, 529.

curred for fetal research through development of non-embryonic stem-cell sources.

C. Bargaining Moratoria

Risk-management and principled-conflict moratoria both target a single contested activity, and are distinguished by the reasons the activity is contested. The third type, bargaining moratoria, facilitates negotiated agreement on matters of shared interest. Bargaining moratoria differ from the prior types in two respects: they may target one crucial piece of a complex, multi-issue negotiation, rather than one salient contested activity; and they involve decisions in which parties' interests are not dominated by either uncertain risks or principled disagreement. With uncertainty not dominant, parties can have reasonably confident views about their interests and the broad shape of agreements they expect to be advantageous. With interests not dominated by principled conflicts, parties are less inclined to demand categorical resolution of the targeted issue in their favor, and more willing to consider compromise via linked decisions on multiple issues.

This type is more complex and heterogeneous than the first two, mainly because the targets of bargaining moratoria are tightly linked to a broad decision agenda. Of our cases, Antarctic claims, the Western Gap, TRIPS non-violation complaints, and nuclear testing fall cleanly into this type, while Antarctic mining and GMOs are mixed cases. In these cases, suitably crafted moratoria can help parties manage their negotiation to seek collective decisions they expect to be mutually beneficial. This can happen in distributive situations involving contested resources or opposing policy positions, so long as parties expect some range of resolutions to be mutually advantageous.[400] It can also happen in collective-action situations, where parties foresee joint benefits from coordinated actions coupled with risks of exploitation if some take those actions while others do not.[401]

In these situations, moratoria can help in two related ways. First, they can stop individual acts that parties find tempting but that risk obstructing agreement or escalating conflict, such as seizing contested resources whose allocation is being negotiated. Such tempting acts may be available to all

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[400] Distributive issues are often analogized to dividing a fixed resource among claimants. Such situations are "distributive" in that a fixed value is divided such that giving more to one party gives less to others. Yet even purely distributive decisions offer mutual benefit, to the extent that there exist specific resolutions that all parties prefer to the alternative of continued conflict or failing to agree. *See generally* SCHELLING, *supra* note 136; RAIFFA, *supra* note 136.

[401] *See generally* RUSSELL HARDIN, COLLECTIVE ACTION (1982); THOMAS SCHELLING, MICROMOTIVES AND MACROBEHAVIOR (1978).

parties, like investing to strengthen Antarctic territorial claims or continuing to test weapons during test-ban pre-negotiations. Or they may be preferentially available to some parties, like U.S. exploration in the Western Gap or technologically dominant states filing non-violation complaints. In either case, a moratorium can remove the risk of escalation during the vulnerable period, by prohibiting the escalatory acts or removing the incentive to do them, as the Western Gap, nuclear testing, and Antarctic claims cases variously illustrate.

A related benefit of a bargaining moratorium can be to delay consideration of a divisive issue that risks stalling a larger negotiation. Delaying hard issues can help parties reduce tension, build communication and trust, or explore creative resolutions.[402] The means to implement a delay can vary. Sometimes, an issue can be delayed simply by not discussing it, as the original Antarctic Treaty negotiators treated mining. But when delay is not possible without some provisional decision, a moratorium can help. The Antarctic claims moratorium, for example, was a way to delay explicit consideration of contending claims—indefinitely, as it turned out. This moratorium also had the virtue of achieving this delay with no prejudice to claims' subsequent resolution. In contrast, the TRIPS case shows that such perfect impartiality is not necessary for a delaying moratorium to be a useful bargaining aid. With no evident way to delay addressing non-violation complaints without favoring one side or the other, the moratorium provisionally resolved the issue in favor of the majority (developing-country) view. Yet its provisional character made it more acceptable to the IP-rich minority than either no agreement or an outright concession, in part because it provided the chance to test in practice, without commitment, how costly the concession would be.

Since bargaining moratoria are procedural tools used in widely varying situations, the determinants of their effectiveness and implications for their design depend strongly on case-specific facts. Their scope must include whatever acts the parties see as tempting, provocative, and threatening to mutually advantageous agreement. A moratorium must also be tolerably even-handed, such that all parties are willing to comply. Termination conditions must let the moratorium last long enough for parties to achieve their shared aim—whether that is reaching agreement on just the targeted issue (as in the Western Gap and nuclear testing cases), or on a broader set of linked issues (as in the TRIPS and Antarctic governance cases).

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[402] J.K. Sebenius & David Lax, *Thinking Coalitionally: Party Arithmetic, Process Opportunism, and Strategic Sequencing*, *in* NEGOTIATION ANALYSIS 153, pg.# (H. Peyton Young ed., 1992).

As in principled-conflict cases, a moratorium that remains long in force may contribute to long-term accommodation, if for example, the initially divisive issues fade in importance over time (Antarctic claims), or the moratorium subtly strengthens into a new status quo that gains normative force even without formal agreement (as all weapons states but North Korea continue to observe test moratoria even with no treaty in force). In these ways, a moratorium that stays in place for decades, even with grudging acceptance and no explicit subsequent agreement, may still aid conflict resolution.

Parties to a bargaining moratorium are exclusively insiders. These moratoria are collectively adopted by bargaining parties to advance shared interests. In all our cases the adopting parties were states, but one can readily imagine similar tactical moves of mutual restraint in diverse bargaining contexts among businesses or other non-state actors, so we suspect this seeming regularity may be an artifact of our case selection—perhaps just because acts of mutual restraint are more likely to be formalized with the name "moratorium" when the actors are states.

D. Mixed Cases and Their Significance

Several of our cases are intermediate between the ideal types. We have distinguished types by parties' principal motivations for the moratorium, but types are also distinguished by the kind of processes established under the moratorium to advance its purpose and promote stronger agreement on how to proceed thereafter. For risk-management moratoria, these processes include research, risk assessment, and development of risk controls. For principled-conflict moratoria, they are ongoing political processes to channel conflict over the contested activity. For bargaining moratoria, they are negotiations for mutually advantageous agreements, enabled by the moratorium's suspension of individually tempting but collectively harmful or destabilizing acts. Our focus is the moratorium, not these other processes that operate while it is in force: risk assessment, regulatory development, and bargaining have not suffered from the same lack of prior scholarly and analytic attention that we find to be the case for moratoria. Yet the intermediate cases illustrate the potential importance of interactions between the moratorium and these processes in determining whether and how progress is achieved in managing the contested activity.

For example, cases lying between the risk-management and principled-conflict types—our most frequent intermediate cases—vary in the status and influence of risk-assessment processes established under the moratorium as well as in the mix of risk concerns and principled opposition. Where principled opposition is stronger, risk-assessment processes have less support, authority, and influence. If some actors are motivated by risks but take an extreme precautionary stance, their influence will be similar to (and indeed, may be indistinguishable from) that of principled opponents, given the impossibility of any assessment process fully resolving uncertainties.

The dumping, whaling, and cloning cases illustrate various ways this type of mixed case can play out. Under the dumping moratorium, assessments attempted to characterize risks, but persistently ambiguous findings allowed both sides to use them to further entrench their positions. Opponents eventually built enough support to harden the moratorium into a full prohibition by making dumping unattractive even to its former supporters, independent of assessment results. In contrast, strong assessment results under the whaling moratorium did not help build agreement, due to persistent principled conflicts. Faced with repeated reports from the Scientific Committee that some species can be hunted without extinction risk, whaling opponents have framed their largely principled objections in risk-assessment terms, criticizing the Committee's methods or invoking uncertainties in enforcement of quantitative catch limits or other precautionary arguments. Strong assessment results have thus not helped bridge conflicts among the parties, and may even have contributed to increased political conflict and reduced legitimacy of the institutions.

In the cloning case, ethical and legal objections were major sources of opponents' concerns, but the expert body avoided addressing these, instead basing its recommendation for a continued funding moratorium mainly on projected health risks to clones. Severe conflict has thus far been deferred, perhaps because research is neither advancing fast enough to provoke public alarm, nor so stifled by limited funding and voluntary controls as to provoke outrage from researchers. We suspect this situation is unstable, however, and heightened conflict is likely under continued research progress—due to either reduction in anticipated health risks to clones (undermining the ostensible basis for the moratorium), or development of new capabilities that more forcefully trigger principled opposition.

These mixed cases suggest limits to the effectiveness of risk-assessment processes, and thus of pure risk-management moratoria, in the presence of mixed motivations. Research and assessment processes may precisely address some actors' concerns, but cannot induce actors motivated by principled or extreme precautionary concerns to accept them as the basis for decisions. They must thus aim for some persuasion at the margin, while also recognizing their own limits and interacting with other, more overtly political processes to pursue broader agreement.

Mixed cases can also involve bargaining moratoria, if the saliency of different motivating factors and processes shifts over time. Uncertainties about risks may shift or decline through research and assessment, so parties come to perceive clearer and more differentiated bargaining interests. Shifts in perceived interests or political alignments may cause principled views to become subject, to some degree, to negotiation. For example, the Antarctic mining moratorium is based on concern about environmental risks, yet allows related research and specifies conditions for future termination. Triggering these conditions would presumably reflect some parties' judgment that the (distributive) gains from mining had grown more salient than the (common) environmental risks. Nations would then have high-stakes distributive interests, with attendant risks of escalation if nations race to pursue resources. Termination conditions of the current moratorium appear to anticipate this risk, in that a proposal to terminate triggers five years further delay, allowing parties time to negotiate a new regime. The long-standing risk-management moratorium would thus shift in purpose, becoming a bargaining moratorium to restrain exploitation while parties negotiate a regime for orderly mineral development.

All the mixed cases illuminate the relationship between the moratorium and the processes that operate under it: assessment and regulatory development, continued political competition, or bargaining. The subsequent processes carry most of the weight in determining whether there is a successful resolution, but the moratorium provides the setting and time for the subsequent processes to operate. The moratorium cannot by itself resolve the conflict or solve the problem, but can by its major design characteristics and rhetorical framing either enable or hinder these subsequent processes that do.

V. Applying Experience: A Moratorium for Climate Engineering

We now apply insights from our analysis of historical moratoria to consider potential uses and conditions of a CE moratorium. We consider each type separately, asking how well CE fits the type and what guidance can be drawn from it. We then identify aspects of the CE debate that diverge from the historical types, and consider how these modify lessons drawn from the three types.

A. Climate Engineering and Risk-Management Moratoria

CE has the clearest points in common with risk-management moratoria, because many objections to CE concern risks of direct environmental harms. A moratorium aiming to address these risks would suspend potentially risky activities to allow time for research and risk assessment; communication among researchers, policymakers, and the public; and development of risk controls. These goals have several implications for moratorium design.

First, the scope of an effective risk-management moratorium must cover the risky activities of concern without obstructing the research, risk-assessment, or other activities needed to learn about and control the risks. In the clearest historical risk-management cases, rDNA and viral research, drawing this boundary was straightforward because the main risks were failures of laboratory containment, subject to assessment and control without continuing the risky experiments.[403] For CE, the risks of concern arise mainly from radiation interventions strong and sustained enough to observably change global and regional climate. These risks could be so severe as to disqualify CE, or particular methods, as acceptable components of climate response. But learning about these risks requires research, including active field experiments.[404] Proposed small-scale experiments present *de minimis* environmental risk, but their difference from global operational interventions is of degree, not kind.

Defining the scope of a moratorium is thus an exercise of drawing a boundary in a continuum, with the additional complication that even the dimensions in which to draw the boundary are not obvious: should it be the area or duration of an intervention, the mass of material injected, or some measure of effect such as radiative forcing?[405] The appropriate scope may vary among intervention methods, if these differ in tradeoffs between knowledge and risk at different scales.[406] Scope decisions must draw on scientific expertise to characterize tradeoffs between impact and insight for different proposed experiments, but expertise alone cannot dictate the decisions—as several years' failure of scientific discussions to advance this question suggest. At best, scientific input can help define tradeoffs and so suggest a range of defensible boundaries, with decisions defining the scope of suspended and provisionally allowed interventions made through some process with broader political legitimacy. The proposal of Parson and Keith[407] to draw two separate thresholds—a large one marking the scope of a moratorium and a smaller one marking the boundary of allowed re-

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[403] Stefan Schafer & Sean Low, *Asilomar Moments: Formative Framings in Recombinant DNA and Solar Climate Engineering Research*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y pg.# (2013).

[404] Keith, Parson & Morgan, *supra* note 4, at pg.#.

[405] MORGAN, NORDHAUS & GOTTLIEB, *supra* note 4, at 37-44; *see also* Parson & Keith, supra note 4, at pg.#

[406] Recent studies suggest test of some radiation methods may require experiments extending over hundreds or thousands of kilometers, rather than tens. David W. Keith et al., *Field Experiments on Solar Geoengineering: An Exploration of a Representative Research Portfolio,* 372 PHIL. TRANSACTIONS ROYAL SOC'Y A, pg.# (2014).

[407] *See supra* text accompanying note 4.

search—represents one attempt to resolve these challenges.

The historical risk-management cases provide only a little guidance regarding actors adopting and bound by a moratorium, suggesting that both insiders and outside authorities can be involved. Scientists interested in CE research have been constructive participants in moratorium debates, and most proposals call for a voluntary moratorium adopted initially by researchers. But there are reasons to think a CE moratorium would be more effective with state involvement. The diversity of potential CE methods suggests that the set of researchers involved may be larger and less tightly linked than in prior risk-management cases, so shared norms may be less effective at promoting adoption and compliance. States, as research funders and regulators, would have practical authority and strong normative influence over the perceived boundaries of responsible CE research. Consequently, while a voluntary, scientist-led moratorium may help stimulate debates on CE governance, an effective risk-management moratorium will probably require government participation.

Termination of risk moratoria is typically linked to developing the knowledge and controls needed to manage the risks that prompted the moratorium. But for CE, adequate knowledge and control cannot be achieved in a single, predetermined step, so termination conditions must be adaptive. Early research will revise perceptions of the efficacy, risks, and relative advantages and disadvantages of different methods, and will also probably identify new questions and uncertainties that suggest further experiments, with new methods and possibly at larger scales. These will unavoidably present new uncertainties and risks, which are informed but not fully resolved by prior research.[408] The balance between knowledge and risk thus cannot be resolved with a one-time decision fixing what is suspended and what may proceed. Rather, moratorium scope must be periodically reconsidered and adapted in light of advancing knowledge and changed conditions.[409] Like the initial scope decision, this adaptive process must integrate expert scientific judgments with legitimate policy judgments, with the relative priority of political legitimacy greater for larger proposed interventions.

In view of the likely controversy over CE, the analytic and political challenges of such an adaptive process will be substantial. The need for an adaptive process does, however, provide some guidance for initial specification of termination conditions. The initial term should be long enough to

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[408] *Compare* Alan Robock et al., *A Test for Geoengineering?*, 327 SCI. 530 (2010), *with* D. G. MacMynowski et al., *Can we Test Geoengineering?* 4 ENERGY & ENVTL. SCI. 5044 (2011).

[409] *See* Long et al., *supra* note 95, at pg.#.

expect significant progress from early research, perhaps ten years, and should allow the possibility of extension with specific terms adapted in response to new knowledge or experience. More broadly, subsequent processes of re-assessment and adaptation should not be designed as purely scientific exercises, but should admit the need, growing with the scale of proposed interventions, for decisions that can be explained and debated in a broader political setting.

B. Climate Engineering and Principled-Conflict Moratoria

Some CE moratorium proposals suggest principled opposition to the enterprise as intrinsically wrong.[410] Such opposition is evident in criticisms of CE as hubristic, or as promoting an exploitative relationship to the natural world. The importance of principled opposition to CE can easily be overstated, however. These arguments have been less prominent than those expressing risk-based concerns, and the involvement of potential CE researchers in moratorium proposals militates against a strong role for principled opposition. Moreover, many seemingly principled objections to CE rely on unstated presumptions about environmental risks. Arguments of hubris or technological over-reach usually presume that meddling with things beyond our competence is not just wrong in itself, but also bound to harm us.[411] Similarly, moral objections to CE rooted in distributive justice depend on assumptions about the distribution of CE's environmental effects and resultant benefits and burdens.[412]

To the extent principled opposition to CE is salient in moratorium debates, we expect conflict over many points of design and process. Those who oppose CE based on principled or highly precautionary grounds will seek a moratorium of broad scope, suspending research activities that would be allowed, even encouraged, under a risk-management moratorium. Such broad scope would pose the challenge of controlling research by purpose rather than methods, scale, or impacts,[413] and would risk over-inclusiveness, suspending research of high scientific value with little connection to CE.[414] Principled opponents would also tend to push for a binding moratorium, imposed by outside authorities; for strict termination conditions; and for bias in design of subsequent risk-assessment or regulatory processes toward unfavorable results and continued strong restrictions.

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[410] *See supra* notes __, __.
[411] *See, e.g.*, CLIVE HAMILTON, EARTHMASTERS: THE DAWN OF THE AGE OF CLIMATE ENGINEERING pg.# (2013); HULME, *supra* note 72, at __.
[412] *But see infra* text accompany note 416.
[413] *See* SRMGI, *supra* note 5, at __.
[414] *See* Long et al., *supra* note 95, at pg.#.

We expect, however, that the structure of the CE and climate-change issues suggest the influence of principled opposition in a CE moratorium will be limited, and will decline relative to risk-management concerns over time. Enacting a moratorium requires building a coalition in which principled opponents must negotiate with risk-motivated actors. With substantial influence of the latter group, the initial moratorium scope is likely to allow some active field research to proceed. As knowledge advances and climate-change impacts grow increasingly salient and severe, we expect risk-based concerns to grow increasingly dominant relative to principled objections. Under this shift, risks of CE will increasingly be weighed against risks of climate change that CE might help limit. Principled opposition to CE will thus shift toward precautionary opposition, whether sincerely or rhetorically, and precautionary opposition will increasingly have to grapple with the two-sided character of associated risks – risks from CE, and risks from climate change – and with the attendant ambiguity in what it means to be precautionary on the CE issue. Some continued precautionary bias against CE could be salutary, given the risks of political failure we discuss below. But we expect a moratorium substantially based on principled opposition to be unsustainable.

C. Climate Engineering and Bargaining Moratoria

The CE debate may initially seem to have little in common with historical cases of bargaining moratoria. The present debate is largely binary—whether or not CE research, or particular types, should proceed—and is being conducted entirely by non-state actors. With a few small exceptions, state officials have not acted or spoken on the topic, and there is little sign of distributive national interests at play—or indeed, of governments having any coherent conception of their national interests in CE. Some commentators have made claims about state interests, suggesting CE is an attempt by high emitters to evade mitigation responsibilities, or a device to shift climate burdens onto poor countries.[415] Current knowledge of CE effects is too preliminary to support such claims, however, and to the extent current research suggests anything on point, it is the opposite: poor countries may benefit most from CE, because they are projected to suffer the worst climate-change impacts.[416]

But states will not be able to avoid the CE issue. As climate-change im-

[415] *See, e.g.*, HAMILTON, *supra* note 422, at __; HULME, *supra* note 72, at __; ETC GROUP, GEOPIRACY, *supra* note 70.

[416] *See* DAVID KEITH, A CASE FOR CLIMATE ENGINEERING (2013); J.B. Moreno-Cruz et al., *A Simple Model to Account for Regional Inequalities in the Effectiveness of Solar Radiation Management*, 110 CLIMATIC CHANGE 649, pg.# (2011).

pacts grow stronger, knowledge and capabilities advance, and the gap between declared global temperature- limitation targets and concrete mitigation actions grows larger, CE will emerge as a potent disruptive force in the international climate agenda. There is little question that this will happen: rather, the main uncertainties are when, how, and with what consequences.

In future negotiations over CE, states are likely to perceive opportunities for unilateral actions that are both tempting and damaging to prospects for cooperative international action. This set of provocative actions will include large-scale unilateral interventions but will be broader, also including various smaller interventions and associated statements and development activities. The availability of such tempting but destabilizing actions suggests that, contrary to initial impressions, CE does exhibit the characteristics that make bargaining moratoria potentially valuable.

A CE moratorium aimed at facilitating mutually beneficial inter-state bargaining would have several distinct characteristics. Its scope would cover acts by virtue of their tempting but provocative character, rather than their anticipated risk. In addition to the obvious case of unilateral large-scale deployment, this might include smaller interventions still judged low-risk but large enough to produce detectable international effects or otherwise arouse international concern; research programs that appear to pursue national advantage; withholding information about capabilities; or expansive declarations of unilateral rights to use CE or respond to suspected use by others. A moratorium on such acts, whether adopted multilaterally or as unilateral statements by individual states, could help prevent suspicion or escalation among states, while also assuaging broader public concern. Such a moratorium could be expanded or adjusted over time, if the initial scope proved over- or under-inclusive. In view of the benefits of avoiding feedbacks from mutual suspicion and escalation, there could be value in adopting such a moratorium well in advance of explicit negotiations over CE governance.

Relevant parties to a CE bargaining moratorium would clearly be states, since it is states that must avoid these destabilizing acts and develop prudent management of CE and climate change. The relevant set might be only those states able to take the identified actions unilaterally—a loosely bounded set of a dozen or so major and intermediate powers, whose acts others would see as a significant global threat.[417]

Termination conditions of a bargaining moratorium should be related to

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[417] *See* Edward A. Parson, *Climate Engineering in Global Climate Governance: Implications for Participation and Linkage*, 3 TRANSNAT'L ENVTL. L. 89, pg.#, (2014).

its aim to facilitate mutually beneficial agreement. The scope and ambition of CE-related agreement that states aim to reach could vary widely, however, from narrow prohibitions of specific dangerous acts, through various forms of governance for CE alone, to a new regime embedding CE in comprehensive governance of climate change. Effective governance is unlikely to be achievable in one step, however, and states must decide how ambitious an agreement to pursue based on political conditions that will evolve during the moratorium. We therefore propose that termination conditions should express a fairly ambitious aim – at least a provisional governance regime for CE – but with some ambiguity in precise termination requirements and a relatively long duration, perhaps an initial ten years with renewal in further ten-year increments. Such a structure would focus attention on CE and signal ambition to develop effective governance, yet avoid either prematurely stating specific governance aims whose suitability cannot be known in advance, or forcing an artificially rapid timetable that could push states toward similarly premature and perhaps wrong-headed governance decisions.[418]

D. Challenges Beyond the Ideal Types

Our taxonomy of moratoria defines ideal types, which fit real cases only approximately. Preceding sections show how CE has commonalities with each type, with resultant guidance for potential uses and design of a CE moratorium. There are also significant points of distinction between the current CE debate and the historical types, which pertain most closely to risk-management moratoria. The most serious prospects for environmental harms from CE are from interventions much larger than any proposed for near-term research, mostly from radiation methods. So from a risk-management perspective, why is any near-term moratorium warranted for CE? One possible response is that public concerns about CE may be more expansive than warranted by consideration of direct environmental risks. Even though large risky interventions are presently remote, a moratorium on such interventions might help calm these concerns and thus help gain consent for small-scale research needed to inform risks of larger interventions.

Another response is suggested by a type of concern present in calls for a CE moratorium that differs from those defining any of the historical types. The concern is that serious harms might arise from CE due to bad future decisions about its development and use—harms that would not occur under more competent, prudent, or wise decisions. We call these socio-political

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[418] *See* Victor, *supra* note 59.

risks, because they project consequences of CE technologies as embedded in the social and political systems that determine their development and use.[419]

Because state action will be central in determining realized risks of CE, all proposed scenarios of socio-political risks depend on assumptions of harmful action by states. For example, future state decision-makers might over-rely on the prospect of CE and avoid tough decisions on emissions cutting. They might develop or use CE methods with the aim of advancing their interests at the expense of other regions, or panic under severe future climate impacts and rush to deploy untested technologies. Socio-political risk scenarios can also involve non-state actors who influence state decisions to steer them in these dangerous directions, and related “lock-in” mechanisms by which seemingly benign near-term research decisions set in motion economic or political processes that subvert policy debates and obstruct prudent and legitimate control over future expansion of the CE enterprise.

The causal claims for these risk scenarios are typically vague, mostly relying on analogies to lock-in processes in other domains, such as network externalities in private technology markets, regulatory capture, or escalation dynamics between adversaries. Other potential lock-in mechanisms include intellectual commitments, bureaucratic routines, and social normalization of how CE is perceived. Such risk mechanisms represent the most plausible objections to small-scale CE research. In their absence, the governance needs of such research are modest, largely based in current environmental regulations and research program management practices.[420]

Risks of this type were not prominent in any of our historical cases, and do not fit well into any of the three historical types. Concern with reckless or malicious acts figured marginally in the two lab-safety cases, but these were assumed controlled by conventional risk-assessment processes and tighter laboratory safety protocols. Risks of provocative state action were central to all the bargaining cases, but these were addressed explicitly by interstate negotiation. In contrast, CE socio-political risk concerns are expansive and vague, so specific risk mechanisms are hard to foresee, assess, or control. The proposed risks are broadly empirical, in that they stipulate certain likely events and outcomes; but because they are mainly driven by socio-economic and political processes, they cannot be adequately ad-

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[419] For an overview of socio-political risk concerns, *see supra* text accompanying notes __-__.

[420] *Accord* Parson & Keith, *supra* note 4, at __; Long et al., *supra* note 95, at pg.#; Parker, *supra* note 71, at pg.#.

dressed by risk-assessment processes that focus on properties of CE technologies and the environment in which they would be used.

In our view, risks of this type must be taken seriously but their strongest forms are so expansive and vague as to be unpersuasive, in part because they rely on analogies to settings with major structural dissimilarities to CE. For example, because key decisions on CE research and deployment will be made by states, the network externalities and rapidly scalable technologies that drive lock-in in private technology markets have no analogy in CE. Indeed, in view of the global distribution of effects and the centrality of state action in any large-scale use of CE, there will probably never be a private market for global climate control. Mechanisms related to adversarial escalation between states are more plausible, but appear unlikely in view of current projections of limits to regional controllability of CE. The most plausible analogy supporting lock-in mechanisms may be regulatory capture in military and public-works contracting, but the high visibility and controversy of the issue, together with early hints that CE can be done with conventional technologies at low cost, tend to weaken private actors' ability, and incentive, to subvert the policy agenda for their profit. And if these risks do materialize, the pathologies of these analogous processes and the suite of governance tools to mitigate them are well known. We acknowledge that these are speculative judgments, but in our view they argue against the strongest scenarios of lock-in from small CE research.

Yet while we reject their extreme forms, these or similar socio-economic risk scenarios may still be serious enough to merit efforts to mitigate them. Since these concerns depend on harmful state action, mitigating them requires developing state and interstate governance mechanisms to promote competent, prudent, and legitimate control of CE. Such a governance project is broader than our current focus on moratoria, but also has implications for moratorium design. Relative to a risk-management moratorium, these mechanisms suggest more risk, from smaller and more innocuous research activities, than would be covered by a moratorium. They thus suggest shifting a risk-management moratorium toward broader scope and stricter termination conditions. Relative to bargaining moratoria, these risk mechanisms suggest additional biases in state action toward harmful outcomes, which may operate even before explicit decisions about CE are on their agenda. They thus suggest a shift to earlier adoption of a bargaining moratorium than otherwise warranted.

These adjustments to moratoria only imperfectly target the socio-political risk mechanisms of concern, however. Fully addressing these is likely to require additional governance measures that more precisely target their hypothesized mechanisms of influence. For example, if the concern is that early research may subtly bias subsequent decisions toward continuance or expansion, research programs can be designed with built-in breakpoints that require explicit periodic decisions to continue, with more rigorous scrutiny and higher procedural burdens for future expansion beyond pre-specified thresholds. Such breakpoints would hinder lock-in mechanisms whatever their cause. Alternatively, if subversion of policy decisions by commercial interests is of particular concern, this can be mitigated by limits on private funding or proprietary technology in CE research. Further examination of such governance mechanisms to control socio-political risks of CE is a high priority, but lies outside our current scope.

VI. CONCLUDING CONSIDERATIONS

The historical importance of decisions regarding development and governance of climate engineering cannot be over-stated. We seek to inform these monumental decisions – in particular, the debate over potential adoption, form, and use of a moratorium related to CE – based on a review of twelve historical cases of moratoria. In view of the empirical and analytical limitations of prior literature on moratoria, we first used these cases to develop a general analytic framework to consider moratorium purposes, characteristics, and effects in particular decision contexts.

We describe moratoria by three basic characteristics: the scope of activities suspended, the actors adopting and bound by the moratorium, and the conditions for its termination. Based on the historical cases, we propose a taxonomy of three ideal types: risk-management moratoria, principled-conflict moratoria, and bargaining moratoria. These are distinguished by the main purposes ascribed to the moratorium, and also differ in the processes that operate under the moratorium to advance subsequent decision-making on the contested activity. Each type has distinct implications for moratorium characteristics and conditions for effectiveness.

Risk-management moratoria suspend an activity based on judgments that it poses uncertain but potentially severe risks, to allow research, risk assessment, and development of controls. Their scope must cover the activities judged dangerous, but exclude related research and risk-assessment activities needed to inform risk judgments. Termination conditions must be related to successful completion of these activities. These moratoria may be supported by coalitions including both insiders – those potentially engaging in the suspended activity – and outsiders, who may share the aim of rational risk assessment and management.

Bargaining moratoria aim to facilitate mutually beneficial negotiations among some group, by suspending tempting but provocative acts that risk obstructing agreement. Their scope must cover activities perceived to pose these risks, and their termination conditions must be related to achievement of the desired agreement. The relevant actors are the insiders, who seek to mutually bind themselves for their collective benefit.

Principled-conflict moratoria are benchmarks of partial success in political struggle over activities subject to moral or ideological conflict. These moratoria merely delay or re-direct conflict, which persists in other fora and is not amenable to resolution by risk assessment or negotiation. We expect pure principled-conflict moratoria to be uncommon, because enacting a moratorium normally requires principled opponents to build coalitions involving different motivations. Principled conflict is more often a factor complicating mixed cases, which weakens the ability of risk assessment or negotiation to reduce conflict on the contested issue.

The cases and analytic framework provide guidance on the potential role and design of a moratorium for CE, derived from each type. For example, if a CE moratorium were adopted primarily for assessment and control of environmental risk, its scope would have to include potentially dangerous interventions – large-scale, sustained radiation interventions, whether for research or operational climate control[421] – and exclude small-scale research interventions needed to inform risks. The wide scale gap between dangerous interventions and those offering near-term research value, and the difficulty of fixing a single threshold between these, motivated the proposal of Parson and Keith to draw two thresholds, a large one demarcating a moratorium and a much smaller one bounding authorized research, with the space between left to be clarified later as knowledge advanced.[422] Pledges by researchers could help promote such a moratorium, but state participation would be necessary for credibility in view of the large interventions it targets. Termination conditions would be linked to progress on assessment and control of risks.

Two aspects of the CE issue, however, distinguish it from historical risk-management cases and challenge attempts to conceive a CE moratorium purely in terms of the risk-assessment type. First, while large dangerous interventions are easily distinguished from needed small informative ones at present – indeed, these are now separated by a wide gap – this will not remain true. Small experiments will only partly inform risks of larger inter-

[421] Large-scale deployment of CDR would also present risks, but any such large-scale program would aggregate many projects, each posing separate site-specific risks. There is thus less rationale for a comprehensive risk-management moratorium for CDR than for radiation interventions.

[422] *supra* note 4.

ventions, and further progress understanding and controlling risks will require larger experiments, with each step presenting new uncertainties and risks despite what is learned from prior research. A risk-management moratorium for CE thus cannot be a single static suspension, but must include processes to adapt under new knowledge and experience, including agreed, prudent expansion of the permissible boundary – while still retaining protections at each step against further expansion.

Second, proposals for large interventions that such a moratorium would suspend do not now exist and appear to be remote. Why, then, consider a risk-assessment moratorium for CE? One possible response is that a moratorium might be warranted to assuage public and political concerns about CE, even if these not justified on grounds of direct environmental risk. By placating these concerns, a moratorium might thus help generate political support to let *de minimis*-risk small-scale research proceed. It would not exactly be a risk-management moratorium, however, except under a more expansive conception of risks of CE as we discuss below.

Alternatively, a CE moratorium might be adopted for bargaining purposes, to facilitate negotiation of mutually beneficial inter-state agreements on CE and related issues. In this case, its scope would target tempting but provocative acts judged likely to obstruct such negotiations. This scope would include the large unilateral interventions targeted by a risk-control moratorium, but would also include additional interventions, development programs, declarations, or other government acts – depending on states' views of what specific unilateral acts were sufficiently disruptive to merit suspension. Such a moratorium would be adopted by high-level state declarations, aiming to include at least the dozen-odd world powers likely capable of unilateral action.[423] Its termination conditions would be linked to participating states' negotiation aims, and would need to be adaptable under partial progress and changed state judgments of governance aims.

Moratoria do not come labeled by purpose, but different purposes suggest different characteristics. For CE, a moratorium to facilitate inter-state bargaining would differ from one to assess and manage environmental risks in several ways. It would be broader in scope, suspending acts based on expected provocation rather than potential danger. It would be adopted by states, at a higher political level. It would be enacted later, with the aim to facilitate negotiation over a control regime for CE. And its termination conditions would be related to success in these negotiations, rather than advancement in knowledge and technical ability to manage risks – although termination conditions for both types would need to be adapted over time,

[423] *Supra* note 417.

since neither of these aims is likely achievable in one step.

We do not expect principled conflict to be a significant factor in enactment or design of a moratorium on CE, because as the saliency of climate-change impacts grows these decisions are likely to be increasingly dominated by risk concerns, and by balancing between risks of CE and of climate change that CE might help reduce. We do, however, expect a significant role for a broader conception of CE-related risks, in particular the politically or socially mediated risk mechanisms discussed above. Concerns about such socio-political risks are prominent in debate on CE but novel relative to the historical cases, where only in the cloning case were similar concerns prominent. While many of the deep challenges posed by such risks pertain to other points of CE governance outside our scope here, these also have implications for moratoria. They may, for example, provide additional grounds for early adoption of a moratorium against large interventions, co-incident with or soon after starting field research programs, even though no proposals to conduct such interventions are imminent. They also suggest drawing the scope of such a moratorium somewhat more broadly, to include smaller interventions than warranted on narrow risk-management grounds.[424] Early adoption of such a moratorium could also help resolve the timing dilemma raised by bargaining moratoria, by raising the prominence of the CE issue and setting broad exploratory governance discussions in motion without creating premature pressure for a completed deal absent the knowledge needed to make a good one.

Returning in closing to our broader and more conceptual aim, the taxonomy and analytic framework we have proposed represents a substantial advance to understanding of moratoria. Beyond the guidance it offers for a potential moratorium on CE, we expect it to be a useful for critical assessment of moratorium proposals in diverse areas of scientific research, technological applications, and challenges in global governance – of which human germ-line modification with CRISPR is the salient current example. As a preliminary step to an analytic understanding of moratoria design and uses, our scheme of course requires further elaboration, including both critical examination from the perspective of other relevant theories and more detailed empirical elaboration of moratorium proposals, implementation, and outcomes in the context of other cases.

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[424] Under a two-threshold approach, lowering the high threshold but leaving the low one in place.