SPRING 2019

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THE UNIVERSITY OF TEXAS AT DALLAS

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ISSUES IN SCIENCE AND TECHNOLOGY

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DEPARTMENTS

ON THE COVER

ADRIAN FERNANDEZ
From *Pending Memories* series,
Untitled No. 5, 2018-19

FEATURES

HUMAN GENOME EDITING

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RESPONDING TO CHINA

John Deutch's "Is Innovation China's New Great Leap Forward" (*Issues*, Summer 2018) does an excellent job of describing the current status of US-China relationships in the context of innovation-based economic competition and, to a certain extent, national security issues facing both countries. He makes the traditional arguments that the United States needs to tighten (not close) its science and technology (S&T) infrastructure, maintain its tech-based entrepreneurial and new venture edge, and continue investing in university-based science, engineering, and advanced education. Basically, run faster. A perfectly reasonable conclusion to reach, but for a material error of omission in his assessment of the current relative strengths of the innovation paths of the two countries.

As he concludes his problem assessment, he writes: "The record clearly establishes extensive illicit technology transfer behavior.... What is striking is the implied judgment that this illicit behavior has been and will continue to be decisive to the advance of Chinese innovative capability. There are few, if any, voices raised to say that significant improvement in Chinese innovation should be expected with the growth of China's economy and the increased maturity of its indigenous science and technology infrastructure *without* any illicit behavior." This strikes me as important and well-articulated, but incomplete.

When considering US innovation-based economic performance, the relevant reference point is not just Chinese performance but also the performance in the rest of world (ROW) beyond the United States. Significant improvement in ROW innovation should be expected with the growth of the ROW economy and the increased maturity of ROW indigenous S&T infrastructure without any illicit behavior.

Since the end of World War II, the United States has led the world in R&D investment and in university-based S&T education. That means, with some inevitable waste and slippage, that it has led the world in innovation. However, the pack of other nations in this race—the United Kingdom, Germany, South Korea, Japan, France, and now China, among others—has substantially closed the gap. The United States is still in the lead but, more than ever, running as part of the pack rather than far out ahead. It is important to recognize that the United States has benefited directly from the gap being closed. It now shares the burden of scientific advance for global civic missions—public health, education, environmental quality—and it benefits directly and economically from scientific and technological advances pioneered elsewhere. In other words, in the twenty-first century, national innovation systems have bled together into a single global innovation system.

In this global system of innovation China stands out for three reasons: the size of its economy; the pace of its economic and innovative growth; and the fact that it is not playing by the rules—explicit and implicit—that govern the other leading countries in the race. So, Deutch's "tighten but don't close" and "run faster" conclusions are good as far they go, but they need to be recast for a multilateral S&T world where neither bilateral trade agreements nor World Trade Organization provisions provide adequate rules (or enforcement) to ensure R&D reciprocity and fair technology transfer, or to govern tech-related foreign direct investment.

This leads down a less traditional path that includes a number of policy innovations:

- Technology-driven industrial policy that allows the United States to lead the pack where it is important for the US economy or national security.
- Revisions to economic and technology policies to increase focus on the US capture of economic benefit from increasing investments in innovation infrastructure around the world (which may require revisions to antitrust policy, patterns of domestic S&T investment, or incentives for US foreign direct investment.
- Substantial revision to, and better US systems to manage and enforce, multilateral agreements and norms (i.e., tighten but not close the US innovation system) in the context of the global innovation system.

There is a great deal of policy work to be done on each of these fronts.

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CAREER DEVELOPMENT IN GRADUATE EDUCATION

In "Critical Steps Toward Modernizing Graduate STEM Education" (*Issues*, Winter 2019), Alan Leshner and Layne Scherer note that career exploration and professional skills development should be core components of an "ideal" graduate program . Indeed, individual mentoring can be highly variable, making access to structured professional development programs an issue intricately linked to equity, inclusion, and retention of early career scientists.

In recent years, many graduate

Continued on page 7 →

PHILLIP K. SMITH III *Lucid Stead* is the homesteader shack in Joshua Tree, CA

From Lucid Stead
Prints and Works by Phillip K. Smith III

The exhibition *From Lucid Stead: Prints and Works by Phillip K. Smith III* is on view at the National Academy of Sciences in Washington, DC, from March 18 through September 13, 2019. It is inspired by *Lucid Stead*, Smith's 2013 installation in Joshua Tree, CA. To create *Lucid Stead*, he transformed an existing homesteader shack into a mirrored structure that, by day, reflected the desert surroundings (as seen in the photograph) and, by night, shifted into a color-changing projected light installation.

Smith creates large-scale temporary installations drawing on concepts of space, form, light, shadow, environment, and change. His practice is informed by his architecture training at Rhode Island School of Design. His works include *The Circle of Land and Sky* (2017) at the inaugural *Desert X* in the Sonoran desert, *Open Sky* (2018), in Milan's 16th-century Palazzo Isimbardi, and *Detroit Skybridge* (2018), commissioned as part of Detroit's Library Street Collective's revitalization effort. Producing extraordinary and communal encounters via installations that explore the transitory nature of light, Smith fosters inexpressibly human, immaterial, and unifying experiences that elude language and defy form, but can be undeniably felt.

Through his pacing of color, reflection, and use of the environment as material, Smith encourages us to slow down and observe our surroundings in new ways.

PHILLIP K. SMITH III *Lucid Stead Elements #1*, 2017, 47 x 8.75 x 6 inches

Brushed anodized aluminum, glass, acrylic, wood, *Lucid Stead* original siding, LED lighting, electrical components, *Lucid Stead* color program. Collection of Rodney D. Lubeznik and Susan D. Goodman.

This sculpture is composed of the *Lucid Stead* installation's raw elements—the original wood siding, the mirror, the white light, the 2x4 structure, and the shifting color—contained within a crisp aluminum frame.

PHILLIP K. SMITH III *Lucid Stead*, 2013, Joshua Tree, CA

Its color scheme is inspired by the color-changing light projected onto *Lucid Stead* at night (as seen in the photograph above).

Continued from page 5

schools have invested in the creation or expansion of PhD-specific career and professional development programs, attributable in part to funding agencies' higher expectations for training grants and funding for innovation in this area. Though promising, access to professional development programs is not sufficient. Whether real or perceived, pressures for research productivity create barriers to attending workshops or exploring careers. Indeed, student attendance and faculty buy-in are two of the four top challenges facing professional development programs, according to a 2018 survey by the Graduate Career Consortium. These challenges speak to the systemic barriers that must be overcome for programmatic investments to have impact.

Six years ago, the University of Massachusetts Medical School proposed a fundamentally different approach: to reframe career development as an expectation for all PhDs by building career and professional development directly into and across the required curriculum, rather than considering them extracurricular. Each educational component is tailored for students' specific year in training, and requires minimal time commitment—important for faculty buy-in. As a next phase, we will be developing evidence-based mentoring resources to maximize synergies between the curriculum and individual mentoring practices.

Funded by a National Institutes of Health BEST award, we are assessing outcomes and impacts of these curricular changes, including attitudes and behaviors of students and faculty. We are fortunate; rigorous program evaluation is difficult and resource-intensive. With few incentives and resources for evaluation, the field of graduate education is significantly less developed than undergraduate education.

To advance graduate education—including career and professional development—the field needs to move toward scientific teaching and consider ways we can better disseminate (and support adoption of) best practices, so that efficient change can happen at a systems-wide, national level. Though multiple organizations have created national communities that actively exchange ideas, much innovation continues to take place within silos. As recommended by Leshner and Scherer—as well as by Ronald J. Daniels and Lida A. Beninson in their article, "Securing the Future of the US Biomedical Research Workforce," in the same volume—there would be great value in working together and across stakeholders to enhance research, innovation, and dissemination in graduate education.

I am working on two multi-stakeholder national initiatives to address these goals. Through one, I3IDP, we are developing toolkits to help universities assess their Individual Development Plan processes. The second is a broader initiative to create a national center to incentivize and support the spread of evidence-based practices in career and professional development by building capacity for

stakeholder collaboration, dissemination, high-fidelity implementation, and evaluation.

As part of national efforts to build an inclusive and equitable training environment, we must reframe career and professional development as a core part of STEM training, as integral as understanding basic genetics principles is to becoming a geneticist. Building national capacity for testing and disseminating educational innovations will accelerate advancement of graduate education practices. As STEM PhD career trajectories continue to evolve, our ability to adapt educational practices will be essential for continuing to attract talented prospective students to PhD training, and ultimately for the health of the scientific enterprise.

Cynthia N. Fuhrmann
Assistant Dean, Career & Professional Development
Associate Professor, Biochemistry & Molecular Pharmacology
Graduate School of Biomedical Sciences
University of Massachusetts Medical School

As a group of current and recent STEM graduate students, we applaud Alan Leshner and Layne Scherer's argument for systemic changes that are essential to improving graduate education. Many of their points deeply resonate with our perspectives, especially the lack of support for students and preparation for jobs outside academia. As this article ironically notes, "Over 20 studies and reports on graduate (STEM) education have come to that same conclusion," while research institutions continue to struggle to create sustained change.

Increasing numbers of PhDs are pursuing nonacademic careers rather than tenure-track faculty positions, but we believe that framing these changes as an effort to "modernize" is problematic. It allows the established academic community to avoid responsibility for and reflection on the institutionalized flaws in graduate student training. Graduate STEM education systems have always had an obligation to be ethical, empathetic, and all-around mindful of the needs and goals of the students, contrary to the implications that this is a contemporary challenge.

Indeed, "real change requires a systems approach," as their article notes, but all levels of the academic ecosystem are not equal in their power and influence. Students have a responsibility to pursue interdisciplinary training and professional development, and faculty have a responsibility to be inclusive and supportive resources for their students. But we believe that the critical role of university administrations and deans is being dangerously overlooked. Leshner and Scherer acknowledge the fact that systematic change is inherently difficult in decentralized systems, which further highlights the importance of holding institutional leadership to a higher standard, since they reflect a small number of individuals with immense local power. The recommendations in the recent National Academies report on which the authors based much of their article should be prioritized and integrated into top-down university hiring requirements, strategic planning, and budget allocations in order to lead by example and shape campus culture to be conducive to change-making at the faculty, staff, and student levels.

Furthermore, a call for changes in funding criteria from state and federal agencies is not sufficient to produce more than superficial results. Successful systematic change will also require putting the spotlight on institutional leaders, challenging them to think creatively and holding them accountable on their promises to prioritize graduate student success.

It is especially important that all levels of leadership within academic institutions support the bottom-up grassroots efforts of graduate students. In the absence of institutional support, these student-led efforts are providing hands-on experience, community building, and public outreach that fill the gap in professional development opportunities. For example, the National Science Policy Network is comprised of early-career scientists and engineers across the United States who are pursuing focused training and professional development opportunities that align with science policy and advocacy career goals. Unsurprisingly, the majority of these efforts operate on shoestring budgets or even on the sheer willpower of student volunteers. In response to the National Academies report, we hope that more university faculty and administrators will step up as allies and advocates who can facilitate the prosperity of graduate student- and postdoc-led endeavors.

Ultimately, early-career researchers who don't feel welcome or supported in academia because of their extracurricular efforts aren't going to stay around to eventually become tenured committee members and advocate for this vision of reformed STEM graduate education. Instead, they will leave, and myopic attitudes toward graduate education will continue to proliferate within the walls of academia. However, the pursuit of healthier and more equitable academic environments; higher-quality of teaching, advising, and mentoring; and expanded support for more interdisciplinary curriculum and research has the potential to benefit not only individual students but also the broader standing of science in society.

Holly Mayton
Michaela Rikard
Avital Percher

ENGINEERING EDUCATION REINVENTED

Richard K. Miller begins his article, "Lessons From the Olin College Experiment" (*Issues*, Winter 2019), by stating that "higher education is notoriously hard to change." This statement is accurate, as this desired change presents challenges, but it is also

PHILLIP K. SMITH III, *Lucid Stead: Focused Views - View 6*, 2013-2019; Archival pigment print, 47 x 8.75 x 6 inches

Lucid Stead: Focused Views

Phillip K. Smith III took this series of photographs in 2013 prior to closing the *Lucid Stead* installation. The photographs are detailed and cropped views of the homestead shack, drawing attention to the relationship between the weather-worn wood, reflection, and the environment.

The day after Smith took these photographs, he decommissioned the work by returning the cabin to its original state with one exception: He did not reattach the original wood siding he had removed, but rather kept it catalogued in his studio. These woods slats would become the originators of the *Lucid Stead Elements* sculptures, one of which is also featured in the exhibition at the National Academy of Sciences.

an opportunity. Based on the successful 20-year history of engineering education innovation at Olin College, Miller, who is president of the college, offers five lessons learned during the creation from scratch of the educational experience there, from working with an initial class of 30 "Olin Partners," to a campus-wide commitment to continual innovation, to the challenges experienced once the inertia of success sets in. Indeed, Olin College has rightly enjoyed tremendous success during a short period, creating an identity as a leader and innovator in undergraduate engineering education.

How do these ideas for education innovation and lessons from Olin College's first 20 years translate to an institution such as the College of Engineering at the University of Illinois at Urbana-Champaign, which is an order of magnitude larger than Olin College and steeped in rich history with an already established strong identity and legacy? Can new pedagogical models take root and flourish at a large research-focused university and college of engineering such as ours? The iFoundry in our College of Engineering was created in 2007 to challenge our traditions and to pilot such models. In the 12 years since its inception, we have learned and confirmed many of the lessons described by Miller. Collaborations between faculty from Illinois Engineering and Olin College have helped solidify the bedrock principle of what is now our Academy for Excellence in Engineering Education (AE3), which offers an additional lesson learned.

That lesson is: communities of practice support faculty-driven innovation. Over the past six years, through our Strategic Instructional Innovations Program (SIIP), 28 teams comprising over 120 faculty have

PHILLIP K. SMITH III, *Lucid Stead: Focused Views - View 4*, 2013-2019; Archival pigment print, 44 x 30.5 inches

led real change in the classroom, including integrating design thinking across curricula, developing a robust online framework for learning and assessment, and enhancing the communication skills of engineering students. A group of Education Innovation Fellows (EIFs), themselves engineering faculty, shepherd the teams in their endeavors. Importantly, these EIFs serve as the connective tissue between different SIIP teams and academic departments, catalyzing communities of practice within the college that support and sustain education innovation. This combination of tight-knit communities working on specific innovations and bridging interactions between teams allows the ideas that work to rapidly spread throughout the college.

Another key component to our success has been taking an engineering approach to education innovation: developing and prototyping educational ideas, measuring the real impact on our students, and then learning whether to pivot or persevere. Our engineering faculty have taken the lead in creating and scaling education innovations by teaching in the same way that we do research—with collaboration, creativity, excitement, measurement, perseverance, and continual improvement. We have found that the broader engineering faculty are more apt to buy in and adopt successful ideas when the innovations are driven by their peers and based on scholarship. By taking this approach, ideas can incubate in more manageable settings before scaling and spreading across curricula to positively impact thousands of Illinois Engineering students each year.

Though "higher education has been notoriously hard to change," change must happen in order for the nation to prepare the future engineers to adapt to the rapidly changing cycles of innovation and to improve the human condition by tackling the grand challenges facing our increasingly connected world. Maintaining disciplinary depth, expanding cross-departmental interdisciplinary breadth, project- and problem-based learning, integrating design-thinking and an entrepreneurial mind-set, and expanding communication skills are all important elements in pursuit of the change. The lessons from the Olin College experiment have brought us many steps closer to realizing this change.

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Dean of Engineering and Grainger Distinguished Professor
Laura Hahn
Director of the Academy for Excellence in Engineering Education
Jonathan Makela
Associate Dean of Undergraduate Education
Professor of Electrical and Computer Engineering
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ADDRESSING SEXUAL HARASSMENT

The article "Treating Sexual Harassment as a Violation of Research Integrity" (*Issues*, Winter 2019) is a necessary read for everyone in all academic institutions. The author, Frazier Benya, was the study director for the recent National Academies report *Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine*. Benya and the committee responsible for the report should be commended for an insightful and long-overdue study on a challenging and important topic. I strongly agree with the overarching argument offered by Benya, and in the interest of furthering conversation about harassment in research, I offer some additional issues for consideration, focusing largely on the recommendations she describes in the article.

Benya makes the case that harassment is a violation of research integrity. Though her assertion seems correct, it raises a range of policy and process questions, including how cases should be investigated and who (on an academic campus) would have jurisdiction over such cases. Regarding jurisdiction, Benya rightly notes that various entities on an academic campus have at least some say over research integrity-related matters (e.g., Institutional Review Boards, Institutional Animal Care and Use Committees, Conflict of Interest Committees). Yet following the logic of Benya's argument that harassment in a research setting might be a form of "research misconduct" or "detrimental research practice," the most likely candidate for who would investigate is the entity on a campus that handles research misconduct cases. In practice, this would raise the question of how the process would complement (replace?) the manner in which cases of harassment (including those outside the research setting) are addressed by the campus through its human resources office, Title IX office, or some similar unit. If multiple offices are involved, which one should a researcher who has been harassed report the matter to? Would a researcher potentially have more than one path of recourse against an accused party?

The topic of harassment awareness and prevention should, according to Benya, be integrated into Responsible Conduct of Research (RCR) training. As an instructor of a range of RCR courses, I agree in principle with that notion. However, some challenges need to be overcome. As Benya indicates, many (most?) RCR instructors may not currently have the relevant expertise to cover the topic of harassment prevention. Also, RCR training programs are being asked to cover an increasing number of topics and often do not have the time or resources to do so adequately. In fact, many institutions rely solely on online training to introduce researchers to RCR topics (so what follows is that harassment prevention may become another online training module at many places). In addition, faculty and staff are not normally required to complete RCR training, yet they arguably are the ones most in need of the training considering the power and influence that they have over the next generation of researchers. And as mentioned above, harassment does not occur only in research settings; thus, a case could be made that a campus-wide harassment prevention effort should be considered alongside the focus on the research environment.

A closing thought: Benya's assessment is certainly correct that academic institutions need consistent and effective measures to prevent harassment. It can be hoped that academia will move beyond a time when "research superstars" who are serial harassers are given a free pass because of their prestige and productivity (achieved at the expense of others' well-being). During the time when academic institutions and other entities are in the process of developing educational initiatives and policies related to harassment, they should use it as an opportunity to address other forms of problematic behavior, including bias, discrimination, and/or harassment against individuals due to sexual orientation, religion, race, national origin, or disability.

Jason Borenstein
Director of Graduate Research Ethics Programs
Associate Director of the Center for Ethics and Technology
Georgia Tech

Sexual harassment has been damaging science and research since women began to take their places in laboratories and on research teams over 100 years ago. There is no doubt that sexual harassment hurts science. That it hurts science makes it a research integrity problem. Frazier Benya's call to begin treating sexual harassment as the violation of research integrity that it is provides compelling justification for highlighting this detrimental research practice in responsible conduct of research training. Addressing this issue begins with awareness, articulation, and recognition of its occurrence and harm, which Benya and colleagues thoroughly catalogue in their recent report. Awareness is a start, but minimizing this detrimental research practice requires much more, including moral courage.

Moral courage is defined by the ethicist and author Rushworth Kidder as taking moral action in the face of danger. Doing the right thing even when it has personal or professional costs is difficult for anyone, but is especially challenging when there is a power differential between parties. It is also in situations of power differentials that sexual harassment flourishes. In

many fields of research, where men are overrepresented in leadership and supervisory roles, and where men control opportunities for advancement, the moral courage needed to stop sexual harassment is the moral courage of our male colleagues.

Not unlike any form of bullying, sexual bullying could be greatly diminished if bystanders mustered moral courage and said, "Stop. We do not tolerate sexual harassment in our profession." Female researchers bear the burden of fending off gender harassment and unwanted sexual attention. Many of these very women and their female colleagues also demonstrate extreme moral courage by calling out such behaviors at the cost of their position, tenure, or career. Solving the problem of sexual bullying does not—and should not—lie with the victims of such behavior. The responsibility to end sexual harassment lies squarely with the perpetrators and their male colleagues. Men must demonstrate moral courage, hold their colleagues accountable, and create a respectful climate for all genders.

Adding material on sexual harassment and skill-building for moral action to research integrity curricula is an accessible first step to begin addressing the issue. Doing so requires no change to how we define responsible conduct of research; it requires only will—and moral courage.

We are obligated to address the harm that sexual harassment causes our profession because we are researchers concerned with the integrity of the scientific enterprise. We are obligated to address the harm that sexual harassment causes female scientists because we are human beings concerned with doing what is right. Meeting these obligations requires moral courage.

Lisa M. Lee
Associate Vice President for Scholarly Integrity and Research Compliance
Virginia Tech

UNIVERSITY AS ECONOMIC CATALYST

John Bardo's description of the contributions that Wichita State University (WSU) has made to the innovation ecosystem in its home city, presented in "Innovation in the Heartland" (*Issues*, Winter 2019), provides a compelling example of how public universities contribute to communities. For decades, public universities have played an important role in the prosperity of the United States' heartland by developing the talent necessary to meet the needs of workplaces while providing students rewarding careers; by generating, incubating, applying, and sharing innovative ideas to transform society; and by enhancing the quality of the places they share with their neighbors, students, faculty, and staff.

But they can't do it alone. Universities partner with community organizations; state, local, and federal governments; entrepreneurs, investors, and small businesses; major corporations and philanthropists; and economic development organizations. These efforts focus on a shared vision for healthier and more engaged citizens, thriving economies, and sustainable and resilient communities.

Universities play an important role in developing broader economic strategies. As neutral conveners of community leaders, they provide trusted information, clarify economic and demographic data, explain the implications of technical and economic change, and facilitate agreements among stakeholders that comprise a metropolitan region.

Authenticity drives WSU's vision. Rather than attempting to copy strategies that have worked elsewhere, the leaders developing the university's strategy engaged in a careful assessment of the assets, industries, needs, opportunities, and cultural milieu of the Wichita metropolitan community. As Bardo (the WSU president until his death in March 2019) explained, one size will not fit all. The strategy's authenticity ensures that it makes sense to those who must play a role in its implementation and that the participants share a common understanding of the region.. As Jane Jacobs, the noted activist and writer on urban matters, once put it, "The greatest asset that a city can have is something that's different from every other place."

Bardo noted that the vision for Wichita's future includes focusing on competitiveness in advanced manufacturing, particularly in the aircraft industry, one of the city's economic strengths. To ensure the competitiveness of US manufacturing—in aircraft and other advanced manufacturing industries—the nation must continue to invest in the foundation and advancement of R&D, production knowledge, and manufacturing skills. This requires partnerships among government, universities, and the private sector in basic and applied research and in developing curricula that embed knowledge of advanced manufacturing technology and mastery of the skills required to use it. The results of WSU's partnerships with industry demonstrate how this alignment improves industry competitiveness while ensuring a bright future for their graduates.

WSU's clear commitment to the economic future of its local community is an illustration of the commitment of many public universities. Another example of WSU's dedication is its pursuit to be recognized by the Association of Public and Land-grant Universities as an Innovation and Economic Prosperity (IEP) University. During this process, WSU is engaging with its community to understand its strengths in economic engagement, to measure its engagement, to document its impact, and to tell the story of its contributions to economic and community development.

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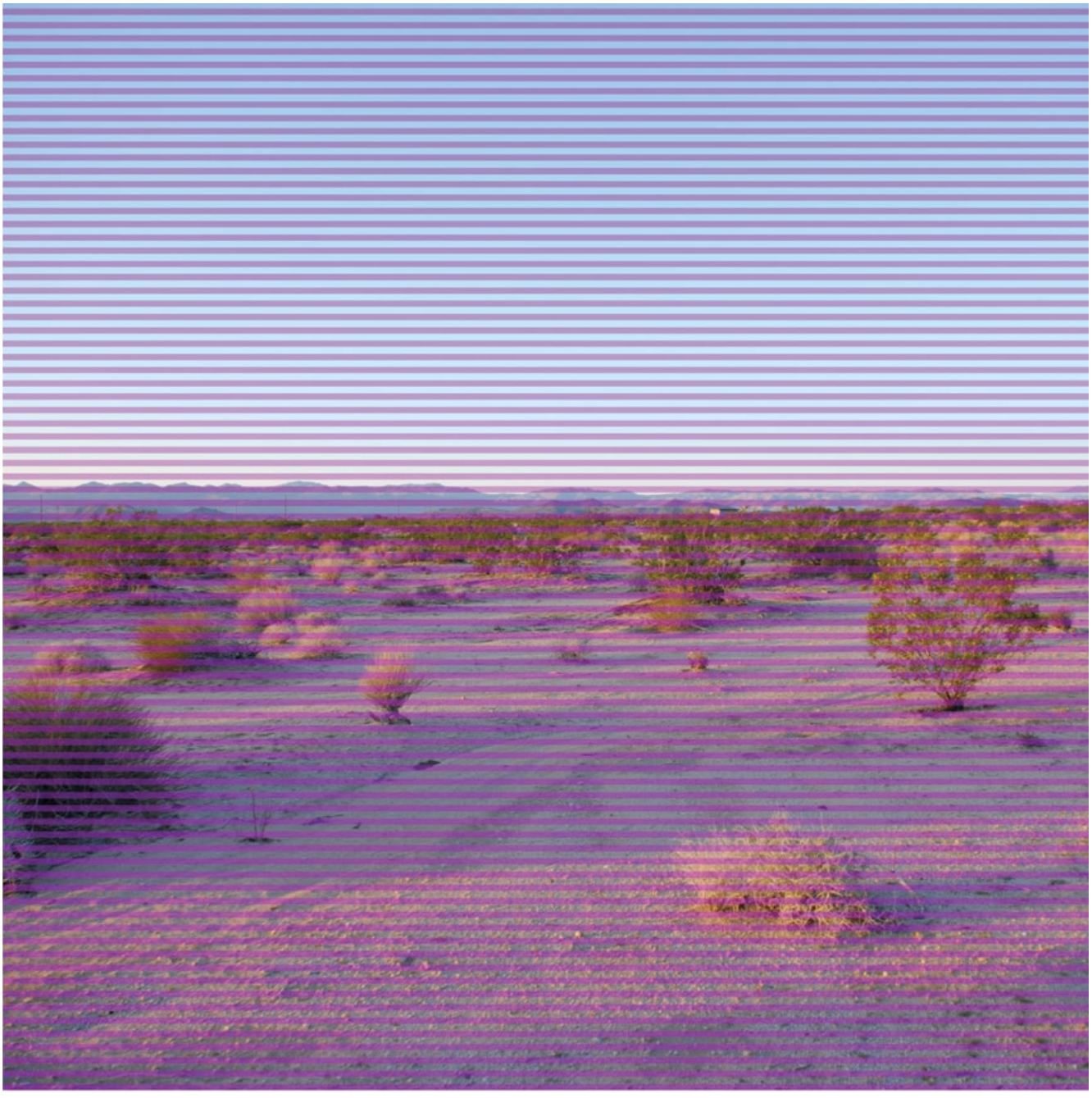


PHILLIP K. SMITH III, *Lucid Stead: Chromatic Variants, Violet*, 2013-2019; Archival pigment print, 18 x 18 inches

Lucid Stead: Chromatic Variants

The *Chromatic Variants* series features tight arrays of transparent colored lines that separate and merge an image of the desert with its color-tinted reflection. From a distance, each image of the desert appears as a color-tinted still of the *Lucid Stead* environment caught in a specific moment in time during the shack's changing color spectrum. A closer look reveals the colored bands separating out the view of the desert environment, recalling Smith's use of the surrounding landscape as a medium placed across the banded, mirrored surface of *Lucid Stead*. Smith's choice of six colors echoes the spectrum of colored light used in the four windows and doorway of *Lucid Stead*, while his use of white and black pays homage to the changing of the desert light from the brightness of the day to the black of the night.

WSU's story is only one of dozens of public universities across the heartland that are partnering to build prosperous and resilient communities.

Sheila Martin
Vice President for Economic Development and Community Engagement
Association of Public and Land-grant Universities
Professor of Urban Studies and Planning
Portland State University

DIVERSIFYING THE RESEARCH ENTERPRISE

In "Challenging US Research Universities and Funders to Increase Diversity in the Research Community" (*Issues*, Winter 2019), Freeman A. Hrabowski and Peter H. Henderson implicitly ask, Who will do science at the highest levels in mid-twenty-first America? The answer must be: all of us. Every population group must be prepared to contribute. The nation cannot afford to waste or underutilize the talents of any group.

The authors challenge the top 30 institutions that are the baccalaureate origins for African Americans who earn science and engineering PhDs, and the top 30 institutions that do likewise for Hispanics, to double their production. This is bold, but achievable. One way or another, we will find the resources. For my institution—California State University, Los Angeles—which ranks number 29 on the list, this will be difficult, but doable. We are a Hispanic-serving, predominately undergraduate, research-intensive public institution. We have few research laboratories, directed by a small but active number of faculty who have been exceptionally successful mentoring undergraduates in research. We will be able to increase our on-campus training a bit, but a doubling is unlikely. Yet we may be able to reach our doubling through partnerships with nearby major research institutions that may have additional training capacity, such as the University of Southern California, Caltech, and UCLA, among others. We need to match Cal State LA's student talent with Los Angeles Basin research training opportunities.

When we do reach that doubling, Hrabowski and Henderson will of course expect us to double that number yet again. So, we might as well get working and earn the institutional sweat equity training of all Americans to achieve success in science and engineering. US colleges and universities should see a solid increase in minority enrollments in the near future. Though the nation is a quarter-century from the tipping point where there will be no majority racial or ethnic group overall, the tipping point comes earlier for young people: 2027 for those 18-29 years old, and 2020 (next year!) for those under age 18.

Collectively, there are 60 valuable stories among the 30 top African American producers and the 30 top Hispanic producers of BS/BA alums who earn science and engineering PhDs. The schools span Historically Black Colleges and Universities, Hispanic-Serving Institutions, many research-intensive private universities, and flagship state universities. There are 60 unique circumstances—including an energetic and committed minority president and dedicated faculty in one; another with an exceptionally supportive campus climate and many minority faculty and senior administrators; and yet another with a phenomenal training capacity and mostly majority faculty who have become exceptionally committed to diversifying American science. What do these schools do? How do they do it? Are there common themes, or are they wonderfully idiosyncratic? What can the 2,500 or so colleges and universities beyond the top 30 learn from the top producers? We need to compile these stories as inspirations so everyone can do better. We should not miss the opportunity to document this richness. I am particularly interested in the stories behind MIT; the University of Michigan, Ann Arbor; the University of Florida; Florida State University; and Cornell University. They are on both lists as top trainers of African American and Hispanic PhD-bound talent. Wow!

Carlos G. Gutiérrez
Distinguished Professor of Chemistry, Emeritus
Founding Director, Minority Opportunities in Research Programs
California State University, Los Angeles

Freeman A. Hrabowski and Peter H. Henderson provide a powerful look at the way forward in utilizing America's entire science, technology, engineering, and mathematics (STEM) talent pool. The authors bring into clear focus the continuing underrepresentation of African Americans and Hispanics in STEM fields. Importantly, they offer sound policy recommendations to support evidence-based and promising program strategies to increase the participation of these underrepresented minorities in the STEM workforce.

The authors' tabular data are informative in identifying the top baccalaureate-origin institutions of African American and Hispanic science and engineering doctorate recipients. The data show striking racial/ethnic differences in baccalaureate origins. Most striking is the prominent role played by historically black colleges and universities that are not research-intensive institutions in educating African American STEM students, whereas almost all the Hispanic students are educated at research-intensive universities. This calls attention to the reality that different strategies may be needed to substantially increase the representation of African Americans and Hispanics, respectively.

Moreover, the authors offer the Meyerhoff Scholars Program at the University of Maryland, Baltimore

County (UMBC), a nonminority institution, as an effective, evidenced-based model applicable to various institutions. A significant strength of that program is that evaluation was an integral component in its design and implementation. Unfortunately, far too many programs to increase the representation of racial/ethnic minorities in science and engineering have not undergone rigorous evaluation—especially by a third party. That UMBC's 20-year rise from being unranked to the number two baccalaureate-origin institution of African American science and engineering doctorate recipients is strong evidence that a nonminority institution can accomplish the goals set out in the landmark National Academies report *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*, which Hrabowski and Henderson cite in their article.

Finally, the essay's opening narrative of the former Meyerhoff Scholars at the NCAA tournament reminds us that in addition to the baccalaureate origins, it is important to know about the careers of underrepresented racial/ethnic minorities.

Willie Pearson Jr.
Professor
School of History and Sociology
Georgia Institute of Technology

NUCLEAR STOCKPILE RELIABILITY

In "The Scientific Foundation for Assessing the Nuclear Performance of Weapons in the US Stockpile Is Eroding" (*Issues*, Winter 2019), John C. Hopkins and David H. Sharp postulate a weakened US deterrent posture due to the lack of nuclear testing since 1992. The article implies that a return to testing is necessary to restore a higher level of confidence to underpin the on-going modernization of the

PHILLIP K. SMITH III, *Lucid Stead: Chromatic Variants, Yellow*, 2013-2019; Archival pigment print, 18 x 18 inches

PHILLIP K. SMITH III, *Lucid Stead: Chromatic Variants, Orange*, 2013-2019; Archival pigment print, 18 x 18 inches

nation's nuclear stockpile. From a purely technical perspective, nuclear testing certainly would increase our confidence, but at what price to our overall national security?

A return to nuclear testing would require, at a minimum, a series of costly nuclear tests that might result in resumed nuclear testing by other current nuclear weapons states and perhaps in the inception of nuclear testing by nonnuclear states that have nuclear aspirations. This is a risky path that should be taken only if absolutely necessary.

The US stockpile has been certified every year since 1997 through a detailed analysis carried out by the National Nuclear Security Administration nuclear weapon laboratories using the tools of the highly successful science-based Stockpile Stewardship Program (SSP), by the Department of Defense (US Strategic Command), and by independent groups advising the government. These rigorous certifications are based on weapons surveillance, nonnuclear experiments, previous nuclear tests, and computer simulations. If Hopkins and Sharp are correct in their assertion that the scientific foundation is eroding because any changes (aging, remanufacturing, etc.) in the stockpiled weapons are not "nuclear-tested, and that "we are gambling with our nation's nuclear deterrent" by trusting the SSP as the basis for certification, then we should not ignore their warning.

Given the current state of world affairs and the 25 years since the inception of the SSP, it might be time that an independent group be appointed to evaluate in depth the level of confidence we should have in our stockpile using the SSP without nuclear testing.

John C. Browne
Former Director (1997-2003)
Los Alamos National Laboratory

Congratulations are due to John C. Hopkins and David H. Sharp for their vitally important article, which has the potential to preserve America's existence. The authors, who are eminent senior scientists at the Los Alamos National Laboratory, had the education, experience, determination, and courage to pursue science and independent thought, while working within a bastion of political correctness.

The Cold War was the world's first nuclear war. It lasted for half a century, and was fought primarily in the world of nuclear science. The United States won it without detonating a single nuke, through superiority in science, strategy, and strength.

However, when that war ended in 1991, US leaders, supported by the public, caused the nation to embark on an unannounced nuclear weapons freeze that—more than a quarter-century later—is still in effect. Every weapon in the nation's arsenal is far beyond its design life. Not a single weapon has been tested during this period. Instead of testing, our nuclear scientists have relied on computer simulations. These computer codes have never been verified.

The authors, with decades of experience in design and testing of nuclear weapons, have produced the first scientific paper to demonstrate why America should not have confidence that our nukes will detonate when our existence depends upon them.

America must immediately resume underground nuclear testing by the Departments of Energy and Defense. We must have total confidence in our strategic nuclear deterrent. We are a quarter-century behind our adversaries in understanding the advanced nuclear sciences of weapons design and weapons effects. We are immensely vulnerable to technological surprise.

Robert R. Monroe
Vice Admiral, US Navy, Ret.
Former Director, Defense Nuclear Agency

SPACE MINING

In "New Policies Needed to Advance Space Mining" (*Issues*, Winter 2019), Ian Christensen, Ian Lange, George Sowers, Angel Abbud-Madrid, and Morgan D. Bazilian provide an excellent overview of the policy and legal challenges posed by space resources activities. The authors, experts in the field, clearly explain the challenges in space resources utilization that subsequently lead to the suggested need for new policies. Their main claim, that policies should be in place in order for space mining to evolve in a sustainable manner, is supported by four specific policy recommendations. The latter correspond to the discussions that are presently taking place in various forums and call for a holistic approach to space mining that will take into account not only the present state of technology and resource needs but also future advancement. Except from describing these recommendations, the authors do not suggest ways to initiate these policies, and although this might be outside the scope of their current article, a further elaboration of these recommendations would be welcomed.

One of the interesting points the authors raise is the identification of a major source of tension in the discussions on space mining; that is, the occasional misconception between commercial space mining activity and the general use of space resources. Whereas outer space is not subject to appropriation, all nations are free to explore and use it, according to international space law. We do not, however, concur with the authors' statement that commercial space resource activity "requires some possession right (not necessarily permanent) to regions in space." Though possession rights in the resources themselves are evidently needed, this is not allowed for "regions in space" as per Article II of the Outer Space Treaty.

By presenting various perspectives on the current status of the industry, it

becomes clear that the abovementioned misconception might not be fully justified. Despite the hardships of the two initial pioneering space mining companies (in fact, both Planetary Resources and Deep Space Industries no longer exist, having being acquired by other firms), several smaller private initiatives are currently developing, such as PTScientists in Germany and the Asteroid Mining Corporation in the United Kingdom. The development of an appropriate framework for the conduct of space resource activities is therefore urgent, and it is essential, as recommended, to involve industrial stakeholders in policy discussions.

With regard to the authors' use of the term "space mining," we note that the term has been considered to have negative connotation, as it might be suggestive of outer space use that does not correspond to the cooperative character of space activities. The preferred terminology is "space resources activities."

We agree with the authors' observation that space resources utilization is now generally seen as not prohibited under current international space law. Their article underlines the importance of interdisciplinary approach and interaction among different stakeholders on national, regional, and international levels in addressing the need for a framework to govern space resource activities. Law usually succeeds technological development in the field of space activities, and space resource utilization is a rare example of almost parallel development. Alongside the need for new policies as presented in this article, it should also be underlined that the momentum for policy to encourage the sustainable development of space resource activities should not be missed.

Tanja Masson-Zwaan
Dimitra Stefoudi
Leiden University
The Netherlands

Christensen et al. make the case for clarifying and streamlining domestic and international legal and regulatory policies to create a new industrial sector focused on space-based resource extraction. The authors are on the money when noting that space mining, or rather space resource extraction (not every resource in space is mined, an example being space-based solar power), is an important national priority for a variety of reasons, not least of which is ensuring US global leadership across all domains in space. The authors end their article by recommending four principles to guide policy formulation to enable the creation of a vibrant new industry.

The exclusive emphasis on policy and regulatory instruments puts the cart before the horse. The authors themselves acknowledge that the economic case for resource extraction is at best inchoate. Recent dissolution of asteroid mining companies such as Planetary Resources and Deep Space Industries shows that the state of technology and business viability of resource extraction is still nascent. Given these challenges, focus on policy and legal guidance, especially at the United Nations level, seems premature.

Although policy and legal frameworks could be helpful in developing global awareness, it would be most useful to promote policy developments in concert with two other dimensions: establishing the value of space resource extraction and ensuring technology development. The term value does not refer to commercial companies being able to make money (which we have already seen is not likely to happen in the near-term), but to the tangible societal value—including economic value—of space resource extraction. Given the falling cost of launch, it may not make sense in every possible architectural configuration to extract water (to make propellant, for example) from asteroids or the Moon and to have propellant depots in space. Part of establishing value means that we need to identify which architectures help make the case for space resource extraction and examine how realistic they are. For example, if the National Aeronautics and Space Administration human missions to Mars use chemical-solar or nuclear propulsion, the amount of chemical propellant required would not be enough to potentially cover the cost of a space-based propellant extraction system.

To examine the economic value, we need to know the cost of a space-based propellant extraction system, which has many steps: prospecting, transportation to and from celestial bodies of interest, excavation of raw materials, processing raw materials into a useable product, storing the product, and finally, use of the product by consumers. Other than prospecting, hardly any of these technologies can currently be considered ready. Technologies for excavation, processing, and storage are furthest behind. There is a clear need to create and mature technology for each of these stages.

It goes without saying that the economic value and technology development are iterative activities. We need to know the technology that will be used, say to extract water from the surface of the Moon, to be able to cost it, to ensure it will, at least eventually, be lower cost than carrying water from Earth.

Together with establishing a clear case for space-based resource extraction, government agencies and private entities, including universities and commercial companies, need to develop a plan to support and conduct the R&D required to take technology to high levels of readiness across all of the extraction and use fronts. As technologies mature, the community can engage more deeply to address the policy, legal, and regulatory issues, which, as the authors point out, are not without their own challenges.

Bhavya Lal
IDA Science and Technology Policy Institute

OCTOPUS FARMING

"The Case Against Octopus Farming" by Jennifer Jacquet, Becca Franks, Peter Godfrey-Smith, and Walter Sánchez-Suárez (*Issues*, Winter 2019) deserves a wide audience.

Most readers will already be aware of the damage that overfishing is doing to the world's oceans, but some of them may believe that aquafarming alleviates this problem. In fact, as the authors point out, when we farm carnivorous species such as octopus, we need to catch three kilograms of fish for every kilo of octopus produced.

Even if that were not the case, however, what kind of human chauvinism is implied by the assumption that we can take animals from any species we wish, irrespective of how little we may know about their cognitive abilities, their social relationships, and their welfare needs, and crowd them into small spaces in order to produce them more cheaply? Nor are we doing this to feed the hungry—the market for farmed octopus is largely affluent and well-fed.

Industrial animal production is ethically indefensible, whether the animals are pigs, chickens, cows, or octopuses. Still, many consumers find it difficult to imagine giving up chicken, pork, beef, or milk, and buying these products from free-range producers could strain their budgets. That doesn't justify buying these animal products from industrial farms, but it does explain why those nightmarish animal factories exist. When it comes to subjecting millions of intelligent, sensitive animals, from a species never before domesticated or farmed, to industrial-scale captivity in order to increase the market for a luxury food, however, the arrogance with which we humans are behaving toward other animals is revealed in all its stark brutality.

Peter Singer
Ira W. DeCamp Professor of Bioethics
Princeton University
Laureate Professor
University of Melbourne

Jennifer Jacquet et al. have penned a diatribe against octopus farming with considerably more heat than light, using generalized assumptions and selected facts. I would like it if no one killed and ate the intelligent and fascinating octopuses that I work with, either caught in the wild or farmed in captivity. But I am a realist; people have to eat. And as the authors point out, octopuses have many characteristics that make them good candidates for "farming." They have a stunning conversion rate of 50% from food ingested to flesh put down (not the 30% noted in the article). They gain weight very quickly, 2% per day if well fed, and reproduce after a year or two and produce many offspring. Hiding in confined spaces, they are well adapted to captivity. They are carnivores, but so are commonly farmed salmon.

The authors predict that farmed octopuses will be a luxury item in "upscale outlets." Maybe for people in northern European countries, but cephalopods continue to be an important food source for Mediterranean countries and all across Asia, often caught by artisanal fisheries and consumed by a wide swath of the populations. People will not "pay more" for wild-caught octopuses, and rather than being "increasingly scarce," octopus populations are increasing; it is only a few local populations that are "in decline." Capture of wild octopuses is not always carried out ethically, either. Many marine animals are simply dumped on the deck of ships, to die of the equivalent of suffocating. One postcapture treatment is to dump the octopus into a barrel of fresh water. The animals die slowly and absorb water, sold subsequently at market at a higher weight due to the added liquid, an unethical and cruel practice. Killing them instantly by destroying the brain is the best technique, carried out by some fishers by biting the octopus between the eyes (not for the squeamish).

The authors seem to have a uniformly negative view of keeping animals in captivity for food as "cruel to individual animals" and "environmentally unsustainable." They predict that farmed octopuses are likely to have "high mortality rates and increased aggression, parasitic infection, and a host of digestive tract issues." Perhaps because they write from the United States, the authors have this poor view of animal welfare and ethics. In Canada where I live, consideration of ethical issues for cephalopods in research has been in effect since 1999. In the European Union, Directive 2010/63/EU requires that cephalopods be given ethical consideration in research, captivity, and during fishing. The United States has no regulation on what you can do to any invertebrate. Perhaps the authors, instead of condemning farming of octopuses, should direct their effort to encouraging similar regulations and making captivity a better situation for octopuses and other similarly held animals.

Jennifer Mather
Professor of Psychology
University of Lethbridge
She is the author of *The Octopus Scientists: Exploring the Mind of a Mollusk*

CLIMATE PHILANTHROPY

In "Climate Philanthropy and the Four Billion (Dollars, That Is)" (*Issues*, Winter 2019), Matthew C. Nisbet makes the argument that investments in climate change mitigation by large foundations have been too narrow in scope to help avert global catastrophe and that the growing influence of philanthropy in solving the climate crisis creates a problem of accountability, where the unelected leaders of foundations seek to exercise global power.

Nisbet is correct in his central argument that a wider set of solutions beyond simply deploying renewable energy and putting a price on carbon is required. The most recent United Nations Intergovernmental Panel on Climate Change (IPCC) report lays out, in stark detail, the calamity the world is facing and the need for urgent and extreme action to dramatically reduce emissions to limit global temperature rise to 1.5 degrees Celsius this century. That's why, at the John D. and Catherine T. MacArthur Foundation, we're advocating an "all-in" approach in

our support of climate solutions. That must include the rapid deployment of renewables and limits on greenhouse gas emissions, which include carbon dioxide, but also shorter-lived yet more potent gases such as methane coming from natural gas production and agriculture. We must also work with the energy industry to explore carbon capture and storage solutions, including the potential of direct-air capture, and to expand the use of safe and secure nuclear power that does not increase the risk of weapons proliferation.

Where we question Nisbet's argument is in his assertion that growing and unaccountable philanthropic investment in climate solutions will surpass national governments in their ability to define the agenda on climate change. Though foundation trustees, presidents, and staff may wish they had that sort of influence, it is hardly the case.

In 2018, MacArthur joined 28 of the world's largest foundations in pledging $4 billion in grants to accelerate the transition to clean energy and reduce the world's emissions. That is a lot of money, but not nearly what it will take to offset the $54 trillion in damage the IPCC report says a 1.5-degree temperature increase will cost the world. That same report says the world needs to double its current energy investments to $2.4 trillion each year between now and 2035, largely on clean energy. And though philanthropic support may help strengthen the civil society actors and innovators working to accelerate climate solutions, a report in 2018 by Drexel University found that fossil fuel producers, airlines, and electrical utilities outspent such groups 10 to 1 in lobbying on climate change legislations between 2000 and 2016.

So, while big philanthropy can certainly help drive an agenda and make key strategic investments, its resources pale in comparison to the more powerful forces we all must increasingly engage with to solve this problem: government and industry. Indeed, it is time to "build a broader political coalition that seeks out nontraditional allies and welcomes challenging ideas," as Nesbit writes. We have also called for that conversation and for stronger government leadership on climate from the city level on up. We encourage greater investment by both industry and government in climate solutions, and we look forward to being a partner in saving our planet.

Jorgen Thomsen
Director, Climate Solutions
MacArthur Foundation

Matthew Nisbet's article is an important contribution to the discussion about the role of philanthropy in addressing climate change. As he notes, climate philanthropy has resulted in several significant achievements. Yet I share his core concern that "as funders have invested in a common road map for tackling climate change, their preferred framing has become so pervasive…that most advocates, journalists, and academics no longer perceive…that there might exist alternative interpretations and courses of action to consider."

I have witnessed this dynamic firsthand through my own work in climate philanthropy. Given the tremendous lift that it will take to decarbonize the global power supply, let alone transportation, buildings, and industry, I am of the belief that we should be expanding the set of potential tools at our disposal. But more than a decade of philanthropy and advocacy has been focused on a narrow tool kit—primarily solar, wind, energy efficiency, and carbon pricing—that is unlikely to solve this challenge on its own (at least if the United Nations Intergovernmental Panel on Climate Change and other credible agencies are to be believed).

In contrast to the well-funded environmental groups that Nisbet describes, the organizations working to advance policies regarding other potential solutions, such as advanced nuclear power, carbon removal, carbon capture, sunlight reflection, and broad-based innovation policy, are deeply underfunded. And though some longtime climate funders such as the Hewlett Foundation have begun to meaningfully widen the scope of their grantmaking, traditional climate philanthropy has been too slow to acknowledge that its funding patterns run the risk of contributing to a "dangerous path dependency," as Nisbet puts it.

Where I respectfully disagree with Nisbet is that I think he overstates the power of big philanthropy to set the climate agenda. In many cases climate foundations are actually following the priorities set by their grantees. And despite Nisbet's claim that philanthropists are "likely to surpass national governments in their ability to define the agenda on climate change," money isn't everything, and the power of public leaders to set an agenda remains unparalleled—even in an era of gridlock and dysfunction. The Green New Deal, which was not funded by big philanthropy, is just the latest reminder of this.

However, what the Green New Deal and much of the work funded by traditional climate philanthropy have in common is that they are well-intentioned but problematic agendas for building effective political constituencies on climate change. We need climate solutions that can help decarbonize the economy and break through partisan gridlock. Witness the passage in the last (highly polarized, highly dysfunctional) Congress of two nuclear innovation bills, the Nuclear Energy Innovation and Modernization Act and the Nuclear Energy Innovation Capabilities Act, both of which had strong bipartisan support.

Accelerating the pace of this work in order to meet the climate challenge requires building a new field of institutions that can work alongside big green groups to provide a diversified approach to addressing climate change. In my view, that is climate philanthropy's most urgent task.

Rachel Pritzker
President
Pritzker Innovation Fund

FROM THE HILL

With the end of the border wall brouhaha, Congress passed omnibus legislation that set funding levels for fiscal year 2019. As anticipated, the budget includes substantive increases for key science agencies including the National Aeronautics and Space Administration (NASA), the Department of Agriculture (USDA), and the National Science Foundation (NSF). This builds on previous congressional actions to boost research at the National Institutes of Health (NIH), the Department of Defense (DOD), and the Department of Energy (DOE). Agencies focused on environmental and climate research—the Environmental Protection Agency (EPA), the US Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA)—were protected from the administration's proposed cuts (see Figure 1 for comparisons).

AAAS currently estimates R&D spending in the FY 2019 omnibus at $151.5 billion, an increase of 6% or $8.6 billion above FY 2018 estimated R&D. This increase was enabled by the 2018 bipartisan budget deal, which raised the discretionary spending caps for FY 2018 and FY 2019. Looking ahead, the new Congress will need to negotiate another budget agreement that would raise spending limits in FY 2020 and FY 2021, the final two years subject to sequestration legislation that called for tight limits on federal spending.

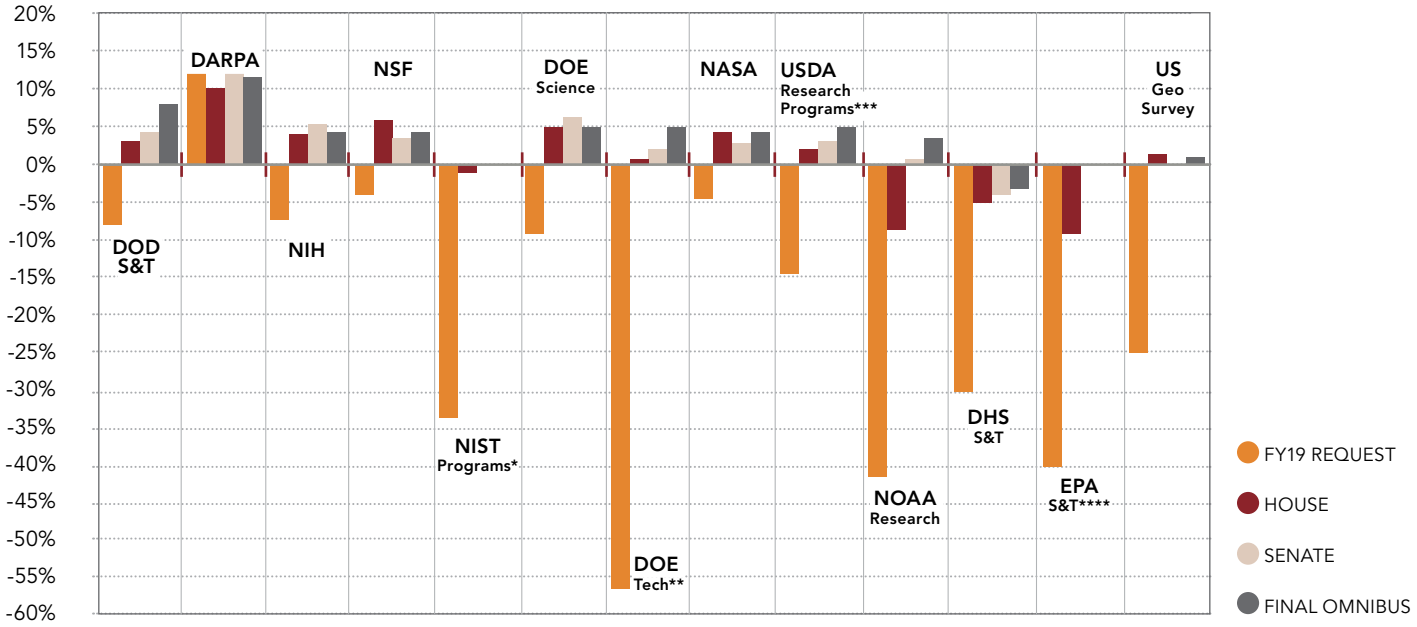
A deeper look into the omnibus reveals that basic research would fare somewhat better than applied research, as seen in Figure 2. This reflects strong congressional support for key basic science agencies, including NIH, DOE's Office of Science, NSF, NASA's Science Directorate, and DOD. In contrast, Congress had sought more limited changes for the larger applied research funders such as USGS and DOE's technology offices.

Total research (basic and applied) in the omnibus is roughly $86.5 billion—the highest amount ever for such spending. Research as a share of gross domestic product (GDP) in FY 2019 would fall slightly to 0.41%.

National Science Foundation. NSF is slated for a moderate 4% increase overall, roughly the same growth rate as in FY 2018. The agency's core research account was given a 2.9% increase, which is not quite as much as envisioned by House appropriators. NSF's Education Directorate received a targeted increase for the Hispanic-Serving Institutions Program. The omnibus funds construction of three research vessels rather than the two requested by the administration and initiates funding for the Antarctic Infrastructure Modernization for Science

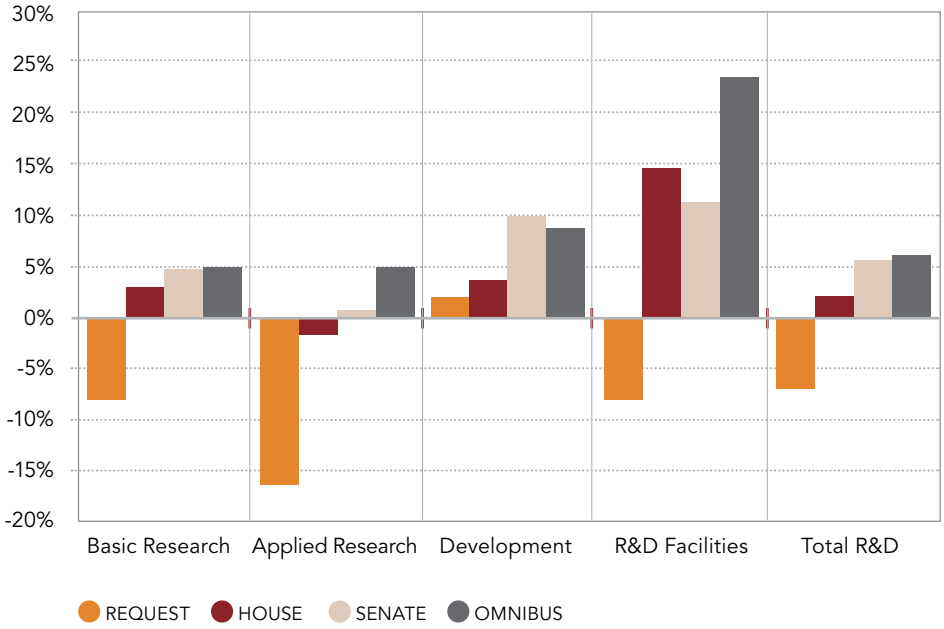
Fig 1. **Select Science & Tech Agencies and Programs in FY 2019 Appropriations**

Estimated percentage change from FY 2018 enacted omnibus, nominal dollars



*Includes labs and industrial technology, excludes construction; flat in Senate and omnibus. **Includes renewables and efficiency, nuclear, fossil, grid research, cybersecurity, ARPA-E. ***Includes ARS, NIFA, ERS, NASS, Rangeland Research, excludes ARS construction. ****Flat in Senate and omnibus.

Fig 2. **R&D by Type in FY 2019 Appropriations**
Estimated percent change from FY 2018, nominal dollars



AAAS estimates based on OMB, agency, and Congressional data. © 2019 AAAS

project, part of a long-range investment program for McMurdo Station.

NASA. The space agency was granted a large $764 million boost in the omnibus, building on recent budget growth. NASA's FY 2019 budget totals $21.5 billion, which is just shy of the agency's peak in FY 2010, after adjusting for inflation. Exploration programs and planetary science were the big winners, with robust funding for the Europa mission and the new lunar gateway, and Earth Science was shielded from the administration's proposed cuts. Notably, the Wide Field Infrared Survey Telescope—the highest priority astronomy mission in the latest decadal survey—was spared from the White House attempt to eliminate it.

Other notable outcomes:

- NASA's Space Launch System (SLS) obtained an additional $48 million for construction of a second mobile launch platform, which will be ready by 2024. The administration did not request funding for the second platform.
- The new Lunar Discovery and Exploration Program received $218 million to develop instruments and other payloads for missions on the Moon's surface.
- The robotic satellite servicing spacecraft known as Restore-L secured a $50 million boost requested by Senate appropriators, whereas the House and administration sought to limit its overall cost.
- As part of the 5.8% increase for NASA Aeronautics, the omnibus includes no less than $35 million for hypersonic research aimed at solving the challenges of high-speed flight.
- James Webb Space Telescope (JWST) development is fully funded thanks to a provision in the bill that adjusts the cap for the telescope to $8.8 billion, an increase of about $800 million above the previous cap. The bill warns that "NASA should strictly adhere to this cap or, under this bill, JWST will have to find cost savings or cancel the mission."

Department of Agriculture. USDA's intramural Agricultural Research Service (ARS) was handed an 8.5% increase for core research, alongside a massive $381 million total for construction and modernization of research facilities in accord with the agency's capital improvement strategy. Meanwhile, the extramural National Institute of Food and Agriculture (NIFA) received a 4.5% increase, which is above both House and Senate appropriations levels. The Agriculture and Food Research Initiative (AFRI), the department's competitive grants program, ended up with the higher House-proposed level of $415 million, a 3.8% increase above FY 2018 levels.

Another noteworthy outcome: the legislation sidelines the administration's attempt to relocate the Economic Research Service and NIFA out of the National Capital Region and directs USDA to report on the costs and benefits of the proposed move as part of the FY 2020 request. However, Congress approved the transfer of National Bio and Agro-Defense Facility (NBAF) operations from the Department of Homeland Security (DHS) to USDA. NBAF will serve as a biosafety level 4 research center when construction is completed within the next five years.

National Oceanic and Atmospheric Administration. NOAA's core Office of Oceanic & Atmospheric Research (OAR) was given an overall 3.2% increase, with limited funding gains across most research programs. Climate research was spared the large cut requested by the House and administration. Also protected from elimination was the National Sea Grant College Program, which received a $3 million increase to $68 million. The US Weather Research Program saw a $3.9 million funding uptick, and funding for ocean exploration and research was increased by $5.5 million.

Funding for the Geostationary Operational Environmental Satellite (GOES-R) and the Joint Polar Satellite System (JPSS) were subject to funding reductions in line with House and administration levels, reflecting a scheduled ramp-down of both programs. Meanwhile, funding for the Polar Follow-On (PFO) was decreased by $89 million to a total $330 million in FY 2019. NOAA's proposal to combine

the PFO with JPSS was rejected, but will continue to be considered by Congress.

National Institute of Standards and Technology (NIST). Two initiatives, the Hollings Manufacturing Extension Partnership and Manufacturing USA, were flat-funded at FY 2018 levels. The administration had sought cuts or outright eliminations of these programs. Following a large one-time boost in last year's omnibus, NIST's research facilities construction account is slated for a 67% funding drop.

Environmental Protection Agency. Congress dismissed the administration's proposed 24% cut to the EPA budget and provided an overall flat appropriation. EPA's Science & Technology account is correspondingly flat, versus a severe 40% cut requested by the administration. Climate change research grants were protected from proposed elimination.

Congress also rejected the administration's attempts to implement a "workforce reshaping" program that would have reduced the number of EPA scientists through organizational restructuring. Meanwhile, the bill continues to prohibit EPA from using funds to implement a mandatory greenhouse gas reporting system for livestock producers.

In total, the FY 2019 omnibus would leave EPA's estimated R&D budget approximately 36% below FY 2005 levels, after adjusting for inflation.

US Geological Survey. The agency's total budget is up by 1.1%—a better outcome than the 25% cut proposed by the administration. Most research areas saw limited funding change. Energy and mineral resource activities received the largest increase, with $9.6 million provided for a new critical mapping initiative and $3.8 million to jump-start energy production in the National Petroleum Reserve in Alaska. Climate Adaptation Science Centers funding, which the administration sought to cut, remains equal to FY 2018.

Meanwhile, the National Land Imaging Program was granted a $5.8 million increase, but core land-change science was flat-funded. Landsat-9 is fully funded at $32 million. The Earthquake Early Warning System was shielded from proposed elimination and flat-funded, and the Volcano Hazards Program was trimmed.

Notably, the omnibus includes funding that allows the Interior Department to implement reorganizations as part of an overhaul plan spearheaded by former Interior secretary Ryan Zinke. The proposed reorganization has raised concerns within the scientific community. The omnibus legislation does, however, urge the department to notify and consult with Congress about planned workforce restructures and reshaping.

Department of Homeland Security. The agency's science & technology account was cut by a total of $21 million below FY 2018, largely as a result of the transfer of operational responsibility for the National Bio and Agro-Defense Facility from DHS to USDA, as noted above. Core research and development funding was essentially flat-funded. University programs would also remain equal to the FY 2018 level of $41 million. The omnibus agrees with the administration's request to replace the Domestic Nuclear Detection Office with a new Countering Weapons of Mass Destruction Office funded at $435 million, with $83 million for R&D programs.

Census Bureau. As part of the ramp-up toward the 2020 decennial headcount, the United States Census Bureau received a full $1 billion increase, matching the Senate and administration's proposed level.

More budget news

Administration to propose FY 2020 budget cuts. In an op-ed published February 25, the acting director of the White House Office of Management and Budget, Russ Vought, signaled that the administration plans a 5% cut to nondefense discretionary spending, which includes funding for key research agencies, in its FY 2020 budget request. It's unclear what baseline the administration is using; nondefense spending is currently scheduled to drop by about 9% in FY 2020 under the Budget Control Act (BCA) spending caps (see related item below). Meanwhile, Vought indicated that the administration intends to increase defense funding using the Overseas Contingency Operations account, which is not subject to the BCA spending caps. Fiscal conservatives have previously criticized use of that account as a way to get around the spending caps.

Will budget sequestration be blocked again? On February 27, the Senate Budget Committee held a hearing to review the Budget Control Act, with the assistant director for budget analysis at the Congressional Budget Office, Terri Gullo, the sole witness. The BCA, which was signed into law in 2011, mandated across-the-board cuts known as "sequestration." Under the BCA, the discretionary portion of the budget, which funds virtually all R&D programs, is set to drop by $126 billion or 10% in FY 2020. Congress previously acted to roll back the sequestration caps through a series of two-year budget deals. Reaching another bipartisan agreement to lift the spending caps would provide greater fiscal room for science investments.

GAO seeks larger S&T role. In late February, the Government Accountability Office (GAO), a legislative branch agency that focuses on auditing and evaluating federal programs, announced that it is seeking a $50.3 million budget boost to $686 million for FY 2020. One purpose of the increase is to support GAO technology assessment efforts, an emerging role of importance for the agency. The GAO established a new Science, Technology Assessment, and Analytics office earlier this year.

House says no to earmarks. House Appropriations chairwoman Nita Lowey (D-NY) announced that the House will continue to prohibit budget earmarks in its FY 2020 appropriations bills. Lawmakers in both chambers have been debating whether to resurrect earmarks, which have been banned since 2011.

NIH addresses sexual harassment

The director of the National Institutes of Health, Francis Collins, and several senior

NIH officials released an update on the agency's efforts to address sexual harassment in science. "To all those who have endured these experiences," the statement says, "we are sorry that it has taken so long to acknowledge and address the climate and culture that has caused such harm. The National Academies report on sexual harassment of women in science found that 'federal agencies may be perpetuating the problem of sexual harassment.' We are concerned that NIH has been part of the problem. We are determined to become part of the solution."

A working group of the Advisory Council to the Director plans to release interim recommendations in June. In the meantime, NIH has been working to demonstrate accountability and transparency regarding sexual harassment, clarify expectations for institutions and investigators, provide clear channels of communication to NIH, and listen to victims and survivors and incorporate their perspectives into future actions. In 2018, NIH followed up on complaints from more than 24 institutions, resulting in the replacement of 14 principal investigators on NIH extramural grants. The awardee institutions themselves took disciplinary action against 21 principal investigators, including termination in some cases.

Fourth space policy directive signed

On February 19, President Trump issued Space Policy Directive-4 to further establish a US Space Force. The directive requires the secretary of defense to develop and submit to the Office of Management of Budget for the president's approval a legislative proposal establishing a US Space Force as an armed service within the Department of the Air Force. The legislative proposal is to outline how the Space Force will "organize, train, and equip forces to provide for freedom of operation in, from, and to the space domain; to provide independent military options for national leadership; and to enhance the lethality and effectiveness of the Joint Force."

OSTP comes to life

In early February, the White House Office of Science and Technology Policy (OSTP) issued a report, *Science & Technology Highlights in the Second Year of the Trump Administration*, outlining the achievements of the administration in a range of areas, including artificial intelligence, cybersecurity, lab-to-market initiatives, ocean science, R&D fundamentals, and space exploration. Some of the achievements highlighted include signing legislation to encourage advancements in unmanned aircraft systems technologies, supercomputer development, and increased investments in artificial intelligence research. The report was released shortly after OSTP welcomed its new director, Kelvin Droegemeier, and with its release, the agency tweeted, "As our Nation stands on the verge of a new era in science and technology, OSTP looks forward to continued work to ensure that American researchers lead the world, and that the United States remains the best place on Earth to explore, create, and innovate."

Droegemeier gave his first official speech to the scientific community at the AAAS annual meeting in Washington, DC, in February. He discussed the US R&D ecosystem and highlighted three pillars that OSTP will address as a means of developing a new construct for the nation's innovation system. The first of the three pillars involves conducting a quadrennial assessment of the nation's research enterprise, including the four sectors that fund research: government, academia, industry, and the private sector. A second pillar involves creating new partnerships and areas of collaboration between the sectors as a means of leveraging its collective strength, and a third pillar will focus on reducing the regulatory burden on the research enterprise.

Call for national research policy board

Stating that the United States has a "fractured, inefficient, inconsistent system" to foster research integrity, the authors of an article in *Nature*, including National Academy of Sciences president Marcia McNutt, have called for the establishment of a national research policy board. Because individuals in the research enterprise typically meet only with their peers, the board would bring together individuals from all sectors of the research community—including funders, journals, academic administrators, and others—to determine best practices in setting an environment of scientific quality and integrity. The board would not adjudicate allegations of research misconduct.

Warning of foreign influences on research integrity

An NIH-appointed panel of experts has warned that US institutions receiving money from NIH need to tighten their security procedures. The eight-member panel, which includes five university presidents, was commissioned to investigate "foreign influences on research integrity" and presented its findings to NIH director Francis Collins in January. In a subsequent letter to more than 10,000 institutions that receive NIH grants, Collins and FBI director Christopher Wray warned about "non-traditional collectors of information" and presented cases where data thieves had shared intellectual property with Beijing, run "shadow laboratories" in China, and stolen confidential information from grant applications.

Although peer review violations are uncommon, several NIH institutes have confirmed "breaches in the integrity" of the peer-review process, and Collins stated that "the magnitude of these risks is increasing." The Trump administration has moved to limit the duration of visas for some Chinese students in certain high-tech fields. Collins acknowledged that the "vast majority" of foreign nationals make valuable contributions to US science, but Wray told Congress last year that the "level of naïveté on the part of the academic sector about this creates its own issues."

"From the Hill" is derived from the weekly Policy Alerts and the reports of the R&D Budget and Policy Program of the American Association for the Advancement of Science.

KEVIN FINNERAN

Editor's Journal

Governance and the **Human Genome**

The first scientific papers about breakthrough developments in the use of the gene-editing tool CRISPR appeared in late 2012 and early 2013. Researchers soon recognized that this relatively accurate and easy-to-use technology makes possible a vast number of applications in plants and animals, including humans. In January 2015 a group of leading researchers and policy experts, some of whom had participated in the legendary 1973 Asilomar Conference on the possible risks of recombinant DNA technology, published an article in *Science* warning that the potential uses of the technology in humans raised profound ethical and social issues that needed to be discussed.

The US National Academies of Sciences and Engineering, the UK Royal Society, and the Chinese Academy of Sciences decided to organize the first International Summit on Human Gene Editing, to be held in December 2015. Even before it was held, the summit itself became a focus of controversy. Sheila Jasanoff, J. Benjamin Hurlbut, and Krishanu Saha published an article in the fall 2015 *Issues*, titled "CRISPR Democracy: Gene Editing and the Need for Inclusive Deliberation," arguing that the planned summit should not follow the Asilomar model of limiting participation to a select group of leading US scientists. Recognizing the broad implications of the new technology, they called for a more broad-based event that would include ethicists, legal scholars, social scientists, and the larger public from across the globe.

The summit organizers listened. Speakers represented a vast array of disciplines and a large number of countries; the meeting was open to the public and was webcast. Following the summit, *Issues* published a group of articles by leading figures from the meeting: organizing committee chair David Baltimore, legal scholar R. Alta Charo, historian Daniel Kevles, and sociologist Ruha Benjamin (*Issues*, Spring 2016). The summit was a quickly organized attempt to create an innovative forum for addressing a perplexing problem. Although it might not have achieved the ideal of a fully integrated, multidisciplinary, broadly representative discussion of CRISPR, it was an enormous step in that direction and a catalyst for all that has followed. (Bias alert: I provided staff support for the summit.)

Interest in CRISPR has mushroomed, with governments, scientific organizations, faith communities, think tanks, and advocacy groups joining the discussion. The topic was back in the headlines in December 2018 when the organizers of the first international summit joined with the Hong Kong Academy of Sciences to host the Second International Summit on Human Genome Editing. The highlight of the meeting was a presentation by the now-notorious Chinese scientist He Jiankui in which he explained how he used CRISPR in engineering a human embryo that resulted in a live birth. Although much certainty clouds our knowledge of what He actually did, his claim ignited a heated round of discussion at the summit and elsewhere. For this edition of *Issues* we invited a few of the leading thinkers in the field to comment on where we are in the process of understanding and managing this powerful tool.

The Stanford University legal scholar Henry T. Greely addresses the immediate practical problem of how to prevent rogue scientists from violating scientific and social norms. He recommends deterrence measures that will make miscreants pay a heavy price for their deeds and some norms and procedures for disclosure when people have suspicions of wrongdoing. Greely ends with an appeal for humility in the scientific community, by which he means a recognition that human genome editing is a technology with enormous social implica-

tions that must be governed not by scientists alone but by the will of society at large.

Peter Mills, the associate director of the United Kingdom's highly respected and globally influential Nuffield Council on Bioethics, develops further what it means to engage society in this discussion. He encourages us to consider the professed purpose of any use of this technology as well as its implications in light of the principles of human rights. He calls for an ecology of approaches that aims to strike the right balance among the scientific, legal/political, and public/ethical frameworks for considering human genetic engineering.

The Dalhousie University bioethicist Francoise Baylis, who was a member of the organizing committee for the first summit, acknowledges the various frameworks that should be applied when approaching this question and places special emphasis on the necessity of achieving broad societal consensus before moving forward with this technology. She explains that consensus is not unanimity and that it is achievable.

Reaching that broad social consensus will necessitate engaging with all the world's religious and ethical traditions. At this early stage in the technology's development, most of us lack a clear understanding of how the world's religions will regard the use of human genetic engineering. Mohammed Ghaly, a professor of Islam and bioethics at Hamad Bin Khalifa University in Qatar, provides a valuable service in explaining how Islamic scholars and ethicists approach the question.

As even the experts struggle to develop a firm and coherent position on CRISPR, members of the public are often bewildered by the choices that society faces. Some special interest groups have formed opinions based on their particular concerns. Families afflicted with genetically inherited diseases find grounds for hope that their progeny will be spared from the disorders. Many members of the deaf community who do not consider deafness a disability view CRISPR as a threat to deaf culture. But it is likely that most people have not yet formed a strong opinion and are experiencing an uneasy mix of fear, hope, and confusion.

The Australian artist Patricia Piccinini has created a series of attention-grabbing sculptures of human/animal hybrid creatures that tap into the anxiety that many people feel about the prospect of human genetic engineering. She has obviously touched a nerve. The images are widely shared on the internet, and an exhibition of her work in Brazil attracted more than 400,000 visitors, leading *The Art Newspaper* to dub her the most popular contemporary artist in the world. Scientists understandably bridle at the unfairness of these disturbing creations, which do not reflect the real risks of the technology, but respecting the full range of responses to the prospect of human genetic engineering is essential to mapping a path forward. Scientists have trumpeted the unprecedented power of this tool, so they should not be surprised that the human imagination will generate apocalyptic as well as beneficent visions.

As difficult as it is to decide what is the medically, ethically, legally, socially proper way to apply the CRISPR tool, the more difficult task could be to make any emerging consensus a reality. Regulating human genetic engineering, along with other world-altering technologies such as climate engineering and artificial intelligence, is an inherently global challenge for which we have no existing governance structure. A number of new approaches are being proposed.

The organizing committee of the second genome editing summit, held in Hong Kong, called for "an ongoing international forum to foster broad public dialogue, develop strategies for increasing equitable access to meet the needs of underserved populations, speed the development of regulatory science, provide a clearinghouse for information about governance options, contribute to the development of common regulatory standards, and enhance coordination of research and clinical applications through an international registry of planned and ongoing experiments." The committee also recommended that the world's scientific academies continue to hold international summits "to review clinical uses of genome editing, to gather diverse perspectives, to inform decisions by policymakers, to formulate recommendations and guidelines, and to promote coordination among nations and jurisdictions."

The World Health Organization (WHO) announced that it is planning to explore ways to regulate the technology. One possibility recently suggested by a WHO advisory committee is to create an international registry of all human genome editing research to promote transparency.

A diverse group of ethicists, social scientists, biomedical researchers, religious thinkers, and legal scholars met for several days at Harvard in April 2017 with a goal of moving beyond a science-dominated discussion. (More bias: I spoke at the meeting.) The group developed the idea of a "global observatory" on gene editing, which would promote interactions across disciplinary and cultural divides. Sheila Jasanoff, one of the meeting's organizers, commented that "The notion that the only thing we should care about is the risk to individuals is very American. So far, the debate has been fixated on potential physical harm to individuals, and not anything else. This is not a formulation shared with other countries in the world, including practically all of Europe. Considerations of risk have equally to do with societal risk. That includes the notion of the family, and what it means to have a designer baby." Jasanoff sees the observatory as a possible model for addressing other powerful emerging technologies.

We won't know for a while whether any of these mechanisms will take root and become an effective tool for managing scientific and technological challenges. But this type of social experimentation is obviously needed. The CRISPR phenomenon has made two things clear: we do not have a broad social consensus on how to proceed with this technology, and we lack an existing mechanism for arriving at a consensus and then implementing it.

J. BRITT HOLBROOK

Philosopher's Corner

Open Science, Open Access, and the Democratization of Knowledge

Science bills itself as working for the common good, but a growing number of scientists, policy-makers, and the social scientists who study them argue that science is too isolated from society to fulfill this promise. They advocate for what they call Open Science—an effort to close the gap between science and society by democratizing scientific knowledge. We can see one aspect of Open Science in efforts to facilitate open access (OA) to research results. According to what has now become the accepted definition of OA, open access requires making scholarly publications (and other products, including data) freely available for anyone with an internet connection to read, download, and reuse for any purpose that accords with community standards.

Expanding access to the scholarly literature has been a goal shared by many researchers and knowledge managers since at least the late 1950s, when the Department of Education began developing the Education Resources Information Center to disseminate the vast amounts of federally funded research on education to state departments of education, as well as to the public. The National Library of Medicine launched MEDLINE, an online bibliographic database of biomedical research, around the same time. In 1969, the Department of Defense's ARPANET—the precursor of the internet—began linking US universities to each other. On July 4, 1971, Michael Hart, then a student at the University of Illinois, typed the full text of the Declaration of Independence and emailed instructions to allow others to download it. Hart's Project Gutenberg, which aimed to distribute as many books as possible to as many people as possible, had begun.

The principle driving these efforts was the desire to democratize knowledge. By the time the World Wide Web became widely available in the 1990s, researchers and knowledge managers had already been considering its possibilities for knowledge dissemination. These considerations, coupled with rising costs for academic library subscriptions to scholarly journals and growing realization of the inequity of restricting access to knowledge to a select few who could afford it, led to the rise of the OA movement.

Despite the steady progress that has been made over the decades, many OA advocates have become frustrated by its glacial pace and pin the blame for the delay on scholarly publishers. They argue that although technology has dramatically reduced the cost of dissemination, scholarly publishers continue to insist on both the value of traditional publications and the high cost of "quality" publishing. Publishers have also remained a step ahead of policy-makers by inventing new ways to take advantage of the push for OA. For instance, publishers developed a hybrid model that allowed the same journal to provide access to articles via the traditional subscription route, as

well as via article processing charges (APCs) that would, if paid by the authors, make certain articles in the journal available OA. This hybrid model essentially enables publishers to double-dip, charging the subscriber and the author for OA articles. Policy-makers are now trying to turn the tables on publishers by putting funding agencies in charge.

To spur the pace of progress, in September 2018 a partnership of 15 European and one US-based research funding agencies formed cOAlition S and developed Plan S to make all research funded by their agencies immediately available for free for anyone to read and reuse. Slated to into effect by January 2020, Plan S could be a game-changer. But in order for it to succeed, funders beyond Europe—especially those from China and the United States—will have to join cOAlition S. China has announced its "support" for the plan but has not officially joined the coalition. In February 2019, India announced its intention to join, and Plan S architects are actively recruiting more members.

Plan S has set a lofty goal and a frenetic pace, but we would do well to remember that open access to the literature is not the ultimate aim. We should keep our eyes on the real prize—the democratization of knowledge pushed for by the champions of Open Science. OA alone is insufficient to change the practice of science to make it more responsive to society's needs.

Plan S could also spell trouble for researchers. *Nature* and *Science* have cited separate studies suggesting that fewer than 15% of existing journals currently comply with Plan S requirements. That puts real limits on where researchers can publish their work. Plan S declares all hybrid journals noncompliant; yet many of these hybrid journals are the publications of choice in various fields of research.

Plan S also includes other requirements that have caught authors in the middle of the struggle between cOAlition S funders and publishers. It mandates that authors retain the copyright to the manuscripts they submit to journals, a move that could empower authors while disempowering journals that typically require authors to sign over their rights to the publisher. Yet it also requires the use of a CC BY license issued by Creative Commons, a global nonprofit organization that attempts to simplify and standardize public permissions to share and use creative knowledge. The CC BY license stipulates that authors must grant permission for their work to be reused by anyone in virtually any way, as long as it is attributed to them. This mandate effectively removes the power of copyright not only from publishers, but also from authors.

Although researchers have reacted in various ways to these demands, these technical details are not at the center of the discussion. Instead, the emerging Open Science ideal undergirds most of the arguments surrounding Plan S.

Advocates describe the Open Science ideal simply as science done right, as a public good that should be practiced in connection with society and societal values. Science done right, in this context, includes considerations of social justice and international human rights. The Open Science ideal requires researchers to pay at least as much attention to scientific responsibility as to scientific freedom. Part of that responsibility is to make the scientific literature freely available to all; but Open Science is more than open access. And although Plan S promotes OA, it might actually interfere with achieving the Open Science ideal because, in its basic design, Plan S amounts to an incremental technical improvement on Vannevar Bush's linear model of knowledge production.

Despite the steady progress that has been made over the decades, many Open Access advocates have become frustrated by its glacial pace and pin the blame for the delay on scholarly publishers.

At the close of World War II, Bush, a respected engineer and even more famous science administrator and adviser, argued that scientists needed both public funding and autonomy to perform the research they felt was most valuable. The research would undergo peer review, after which the results would be stored in a reservoir of scientific knowledge from which society could draw when needs arose. Once they passed their work through peer review and published it in a scientific journal, the scientists had met their responsibilities. It was up to society to find the knowledge and apply it. The linear model was never supposed to describe how research actually happens; it was a rhetorical move designed to secure a place (and funding) for researchers to pursue the science they wanted to, safe from societal demands.

By charging for subscriptions to gain access to this knowledge, scientific journals erected an additional

barrier between science and society that fit nicely into Bush's design to keep science autonomous from society. Plan S will expand access to the results of research by removing the subscription paywall, but it will not make scientists any more responsive to society's needs. Plan S might be a benefit to the science system but not necessarily to society. It might also be a bane to scientists.

Plan S hopes to flatten the hierarchy of scientific journals that drives researchers to seek publication in a handful of highly prestigious journals. Researchers care about where they publish, we are told by Plan S advocates, only because they are evaluated on the basis of the Journal Impact Factor (JIF). Plan S promises to eliminate the JIF, and because everything will be available for free, it will not matter where researchers publish. The current gap that separates more and less prestigious journals will disappear, and all knowledge will become part of one big commons, openly available to everyone. This is democratization of a sort, but it falls short of the real democratization of knowledge as outlined by the Open Science ideal. Real democratization would require connecting the supply of knowledge with the demand for knowledge. Instead, under Plan S, researchers will have met their responsibilities once they publish their papers in a compliant journal or repository.

At this time, the list of compliant journals is quite small and is dominated by those that charge APCs to make articles OA. The list of compliant repositories, which would allow compliance without forcing researchers to pay to publish, is even smaller. Plan S suggests that once the publishers flip to OA, there will be enough money in the system—presumably savings on subscription fees—to cover these APCs. In the meantime, it is unclear whether researchers without funding will be able to afford to publish under Plan S. This potential difficulty is not the concern of cOAlition S, however. Plan S is top-down, forcing researchers and publishers to comply with funder mandates.

Contrast the cOAlition S approach with that put forward by another organization, AmeliCA, coming from Latin America and the Global South. Launched as the result of a UNESCO special forum on the democratization of academic knowledge, AmeliCA is bottom-up, stemming from the experiences of academics who are trying to both engage society and engage in a worldwide scholarly conversation. According to Arianna Becerril García, president of AmeliCA, founder of the Network of Scientific Journals of Latin America and the Caribbean, Spain, and Portugal (Redalyc), and professor of computer science at the Autonomous University of the State of Mexico, the Latin American scholarly ecosystem regards publishing as a community commons, not an industry. In fact, much of the scholarly publishing in Latin America takes place across OA platforms such as Redalyc, and also including SciELO and Latindex, which were created and led by researchers with support from their universities or national funding agencies. The focus of these platforms is twofold: to provide a place for national or regional journals that focus on publishing research relevant to those areas, and to raise the profile of such journals so that the authors who publish there can contribute to the worldwide scholarly conversation. These platforms aim to contribute to the democratization of knowledge by making relevant research openly available, as well as by opening up the international scholarly conversation to include researchers from Latin America and the Global South.

AmeliCA has not only its own proposals for how Open Science should be achieved, but also a message to cOAlition S and others who may have abandoned the Open Science Ideal. "From the Global South," says a post on AmeliCA's blog, "it is seen with concern that a model is being established that again opposes the South and the North, instead of seeking the construction of common platforms that use technologies that prevent, from now on, the possibility of simply being controlled."

As opposed to funder mandates that push researchers toward paying fees to make their articles immediately available in compliant venues, a requirement that would favor researchers with more money, AmeliCA advocates enhancing the infrastructure for Open Science at academic institutions. Instead of control from above, AmeliCA suggests that academic researchers and academic institutions should retain control of academic knowledge production. In the Latin American context, this sort of autonomy is meant to guarantee that scientists can connect their research to regional, national, or local needs; it is very different from autonomy in Bush's sense. In place of the desire to achieve OA above all else, AmeliCA holds that the societal impact of science is the justification for OA. Instead of insisting that technology has determined our policy decisions, AmeliCA suggests that we make policies to use technology as a tool to realize the democratization of knowledge.

Plan S may yet succeed in achieving immediate OA for publications supported by cOAlition S funders, but its ultimate impact will depend in large part on who else joins. As written, Plan S focuses on achieving OA, rather than using OA as a means to achieve the Open Science ideal. It is possible that Plan S supporters simply equate OA with democratizing knowledge. If so, we have not advanced very far since the heyday of the linear model.

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MATTHEW C. NISBET

Sciences, Publics, Politics

The Green New Dilemma

Following the demise in 2010 of federal cap-and-trade legislation aimed at slowing greenhouse gas emissions, environmental donors gathered in Chicago in 2011 to meet with David Axelrod and Rahm Emanuel, pressing the two senior White House advisers on why President Obama had not lobbied more aggressively for the bill. Despite devoting half a billion dollars to the cause, backers of the legislation struggled to win a single Republican vote, Emanuel responded. The previous year, he had advised the coalition of environmental and corporate leaders behind the legislation to shift support to an energy bill that did not include an economy-wide cap on carbon dioxide emissions. Emanuel was focused on putting points on the board, moving forward cautiously in order to protect Democratic control of Congress, playing a long game intended to build momentum for policy over an eight-year Obama presidency.

But the coalition and Democratic leaders in Congress chose to move forward with the cap-and-trade bill. In response, conservative groups and Republican leaders, aided by Fox News and libertarian donors, efficiently folded their opposition to the legislation into a larger narrative opposing big government, taxes, "socialism," and "Obamacare," spreading doubt about climate science in the process. The strategy mobilized Republican-leaning voters during the 2010 midterm elections, costing Democrats their majority in the House of Representatives, shutting the door on climate legislation during the rest of the Obama presidency. "Your DNA and my DNA are so different," Emanuel reportedly told the environmental funders gathered at the Chicago meeting. "I'm about trying to get to first base. You're about trying to hit it over the fence."

Eight years later, having finally regained majority control of the House, Democrats and their environmentalist allies once again face a similar dilemma, one that has split the party heading into the 2020 elections. On one side are progressive insurgents who argue that Democrats should close ranks in support of the Green New Deal, an audacious plan sponsored by Sen. Edward Markey (D-MA), one of the authors of the 2010 cap-and-trade bill, and Rep. Alexandria Ocasio-Cortez (D-NY), that urges a "national, social, industrial, and economic mobilization not seen since World War II and the New Deal." The resolution calls not only for centralized government involvement in labor and energy markets and the setting of industrial policy to zero out greenhouse gas emissions within a decade, but also for dramatic expansion of social welfare spending, including a government jobs program, free college tuition, and Medicare-for-all.

The overarching aim of the Ocasio-Cortez/Markey plan is to transition the United States into a social democracy in the mold of Norway, Sweden, and Denmark, and then to spread a similar Green New Deal model across other countries of the world. As argued by backers of the resolution, the long-standing problems of climate change and income inequality share common causes, rooted in a "neoliberal" capitalist economy that favors corporations, economic growth, and the wealthy over everything else. This imbalance in power has not only created a climate emergency, they argue, but also has perpetuated the historic oppression of the working class, women, the disabled, people of color, and other "frontline and vulnerable communities."

In this regard, progressives see climate change as not only a crisis but also an opportunity. As argued by Naomi Klein in her 2014 best-selling book, *This Changes Everything: Capitalism vs. the Climate*, a climate movement inspired by bold policy proposals such as the Green New Deal, and equal in intensity to political movements that battled slavery and colonialism, would allow an alliance of left-wing groups to achieve a diverse range of social justice goals. For progressives, climate change, she argued, is the best chance to right the "festering wrongs" of colonialism and slavery, "the unfinished business of liberation."

On the other side of the Green New Deal debate are left-of-center Democrats led by House Majority Leader Nancy Pelosi (D-CA). Heeding the lessons of cap-and-trade, these more pragmatic-minded legislators acknowledge the urgency of the problem but instead favor a series of climate and energy bills that have a stronger likelihood of eventual passage, establishing

momentum over the long term, while protecting Democratic electoral chances. Examples include R&D funding for clean energy and negative emissions technologies, narrowly targeted regulations aimed at cutting powerful greenhouse gases such as methane and hydrofluorocarbons, a national clean electricity standard, a carbon fee and rebate program, stronger energy efficiency standards for homes, buildings, and transportation, and an infrastructure funding bill that prioritizes resilience.

These pragmatists calculate that divided party control of government and intense hyper-partisanship are likely to endure for many years to come. Even if Democrats during the 2020 elections recapture the White House and Senate and maintain control of the House, the political structure of the nation suggests that these victories will be temporary. Since 1968, Democrats have controlled the executive and legislative branches *for a total of eight years out of 50*. To survive swings in party control, any climate and energy policy must be able to unify support from progressives and centrists but also win backing from at least some conservatives.

Green New Deal proponents ignore the unique cultural and regional differences that have characterized the country since its founding, and that make a US-style social democracy virtually impossible to enact.

Many pragmatists also understand that given the sizable lobbying advantage of the fossil fuel industry and its allies, successful legislation will need the backing not only of some Republicans but also of at least a few major industry members. In the cases of health care reform and tobacco regulation, after decades of grassroots activism, historic bills passed because a pragmatic coalition of leaders granted concessions to long-standing industry opponents. A similar strategy is likely to apply to future climate change legislation. The pragmatists also recognize that to have a chance of rapidly decarbonizing the US economy, future legislation cannot focus solely on wind, solar, and batteries—the implausible path that many progressives insist on—but must also target innovation, cost reduction, and deployment across a broad range of low-carbon technologies.

In contrast, Green New Deal advocates have framed the choice for Americans in starkly binary terms: Either join us in a utopian quest to transform the United States into a social democracy or face the catastrophic consequences of a dystopian climate future. There are no other choices. In fact, their battle is as much against moderates and pragmatists as it is against conservatives. "Moderate is not a stance," Ocasio-Cortez told the audience at the 2019 South by Southwest ideas festival. "It's just an attitude towards life of, like, 'meh.' " The Super PAC Justice Democrats, which spearheaded Ocasio-Cortez's Democratic primary defeat of a longtime moderate incumbent, has plans to do the same during the 2020 election cycle to other centrist Democrats who do not fully support the Green New Deal or other causes such as abolishing the US Immigration and Customs Enforcement agency.

Yet in their push for a social democratic America, Green New Deal proponents ignore the unique cultural and regional differences that have characterized the country since its founding, and that make a US-style social democracy virtually impossible to enact. The much-admired northern European social democracies of Sweden, Norway, and Denmark are characterized by a relatively unified political culture shared across national populations comparable in size to New York City, living together in relatively close geographic proximity. This makes it far easier in these countries to maintain consensus on behalf of generous social welfare programs and to win support for centralized decarbonization efforts. In contrast, the United States is a nation of 325 million people, more than 50 times bigger by population than Denmark or Norway. Americans are divided geographically across four million square miles and 11 distinct regional cultures, as Colin Woodward documents in his 2016 book, *American Character*. These regions never have been, nor are they likely ever to be, united by common purpose or principles.

The Green New Deal reflects the groupthink of Yankeedom and the Left Coast, regions that include New England, New York, the Upper Midwest, coastal California, Oregon, and Washington. Public sentiment in these regions has always tilted toward confidence in government as a tool for human betterment, complemented by egalitarian and communitarian values that prioritize the welfare of the most vulnerable and the protection of nature over the economic rights of individuals. Notably, three-quarters of the 90 current House cosponsors of the Green New Deal resolution represent districts in these regions that for the most part are also safe seats for Democrats. More than half of the cosponsors are from just California, New York, and Massachusetts. In contrast, the regional cultures of Greater Appalachia, the Tidewater region of coastal Virginia, Maryland and North Carolina, the Deep South, the Far West, and parts of the Southwest are characterized by either an intense commitment to individual sovereignty and personal liberty or an aristocratic libertarianism highly resistant to federal government dictates. Not surprisingly, only a handful of Democratic cosponsors of the Green New Deal resolution represent districts in these regions, which tend to lean Republican and conservative, and therefore require a Democratic officeholder to tread carefully.

Not only are the social democracy aspirations of Green New Deal proponents at odds with America's pluralistic political

culture, but the proposal is also an anachronism, a form of political nostalgia in which progressives articulate their vision for transformative policy via the lens of what they believe was so special about mid-twentieth-century America. Such nostalgia, however, blinds advocates on the Left to the defining features of the present that any ambitious climate and energy strategy must navigate.

As progressives tell their version of the story, after passage of the New Deal in the 1930s and the Great Society programs of the 1960s, the United States was on its way to becoming a social democracy, only to be halted in 1980 by the emergence of radical neoliberal economics and the election of Ronald Reagan. By the 1990s, neoliberalism had infected the Democratic party, as the Clinton administration insisted that countries agreeing to the 1997 Kyoto climate treaty adopt a market-based, tradeable emission permits approach rather than command-and-control regulation, and as Clinton joined with congressional Republicans to cut social welfare benefits and loosen regulations on Wall Street.

But history is far more complex than this simple story, notes Yuval Levin in his 2016 book, *Shattered Republic*. As progressives have battled to combat problems such as climate change and inequality via enhanced federal spending and regulation, relying on technocratic expertise to justify the shift, multiple dimensions of American society have been moving in the opposite direction, becoming more diffuse, decentralized, and distrustful of technocrats. It is true that the mid-century years that progressives yearn for featured low income inequality, much higher unionization, and robust economic growth, but this economic prosperity was enabled by a two-decade lack of global competition, as Europe recovered from World War II and Asia embarked on economic modernization.

The brief historical moments for which progressives wax nostalgic were also periods of unusually high institutional confidence and optimism about government. When Lyndon Johnson was elected president in 1964, in a span of a few years he achieved landmark civil rights, Head Start, Medicare, and Social Security bills at a time when 77% of Americans said they trusted the federal government "always" or "most of the time" and as his Democratic party held two-thirds majorities in Congress. A similar level of trust in government existed in 1970 when Republican president Richard Nixon signed into law the Clean Air and Clean Water Acts and established the Environmental Protection Agency. Today, during an era of perpetually divided party control of government, trust stands at just 18%.

Over the past half-century, writes Levin, as federal government has become decentralized, more fragmented, and more distrusted, so has almost everything else in society, as a tightly wound, cohesive body politic forged in the aftermath of World War II dispersed in all directions. We moved from a mid-century culture of cohesion and solidarity that was focused on public service, community, family, and church to a society that by the 1970s had become a culture focused on the Self. The best life became one of "maximum self-expression, self-actualization and maximum personal freedom, economic as well as lifestyle," observed the *New York Times*'s David Brooks in a recent column. Today, as Brooks explained it, absent any shared sense of national identity, Americans on the Right view "our" kind of people as under attack from "theirs," so that the solution is to "erect walls, build barriers and fight." For their part, Americans on the Left see in neoliberal America "the story of class, racial and gender oppression" whose solution "is to rise up and destroy the systems of oppression."

The Green New Deal intentionally magnifies these tribal distinctions. In the quest for climate progress, the goal is not to broker cross-alliances between the center-right, center-left, and left wing, drawing on the best ideas that those factions can offer, but rather to build progressive power. Yet what might be good for progressives in wresting control of the Democratic party from moderates is not likely to help combat climate change or be good for the country. People who are made conscious of their group membership are driven to participate on behalf of their groups, not the greater good, writes Lillian Mason in her 2018 book, *Uncivil Disagreement*. The tactics that progressives are employing, defining climate change as an "us versus them" battle between an intersectional Left and everyone else, only increases already intense political prejudice and animosity, stoking a righteousness that caricatures conservatives and the fossil fuel industry as "deniers" incapable of reason, and moderates as enablers of their evil.

Still, it is not enough for moderates and conservatives to poke holes in the reasoning of progressives, or to dismiss the Green New Deal out of hand. Ideas that empower a vital center of elected officials and decision-makers will be essential, helping to forge coalitions on behalf of politically viable and effective policy approaches that begin to make decisive progress toward a resilient, net-zero carbon economy. Among the major investments needed will be the fostering of a new solutions-focused conversation that critically evaluates conventional narratives about climate change as a social problem, exposes faulty thinking, holds those in power accountable, promotes cross-cutting dialogue, cultivates optimism and cooperation rather than anger and polarization, and encourages better decisions and more inclusive politics by widening the scope of available technological and policy options rather than narrowing them as part of a self-defeating strategy to distinguish "us" from "them."

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HENRY T. GREELY

How Should Science Respond to CRISPR'd Babies?

The scientific community's leaders should enforce deterrence, create disclosure, and express humility.

On November 25, 2018, much of the world (including me) was shocked to hear of the birth of the world's first babies produced from embryos whose DNA had been edited by the Chinese scientist He Jiankui, using the newly emerging technology called CRISPR (a handier name than the official "clustered regularly interspaced short palindromic repeats"). We still have been told little about what happened, and we have no independent or reliable verification. But the ripples of this event have not waited for confirmation: distrust, concern, and even outrage have spread. Science itself is at risk.

Whatever the full story, the He Jiankui affair has clearly been a fiasco. The experiment went forward despite a gross imbalance of risks and benefits, highly questionable consent, apparent fraud, inappropriate secrecy, and violation of a strong global consensus against human germline genome editing at this time. People were, rightly, shocked by this bolt from the blue, one that reinforced an unfortunately already widespread image of ambitious rogue scientists, casting He as a Chinese version of Drs. Frankenstein and Moreau.

Science does not have a president, prime minister, or pope. But science does have leaders, individual and institutional, and those leaders have some influence over public perceptions. Leaders reacted—but their reactions were insufficient. Now they badly need to do three things: enforce deterrence, create disclosure, and express humility.

PATRICIA PICCININI
The Rookie, 2015; fiberglass, silicone, hair; 48 x 65 x 46 cm

Enforcing deterrence

He Jiankui expected to be hailed as a hero, or at least to be seen as a pioneering figure. He gambled his high-flying present for the hopes of an even higher-flying future. Thus far, it seems he bet wrong. Far from being a hero, he has been (almost) universally condemned and appears to be facing criminal prosecution in China. But whatever happens in China, science needs to ensure that he is ostracized. No future ambitious scientist should see this kind of experiment as anything but a suicidal career move.

In 1980 when Martin Cline, a biomedical scientist at the University of California, Los Angeles, violated ethical rules by pursuing the first (unapproved) gene therapy trials, he lost positions and grants; his career never recovered. Hwang Woo-Suk, a veterinarian and biotechnology researcher at Seoul National University, acted much worse by fraudulently claiming to have cloned human embryos. Until his fraud was discovered in late 2005, Hwang was a hero in South Korea, where his face graced a postage stamp. Following the revelations, he was fired from his faculty position, lost all his grants, and in 2009 was convicted of fraud and embezzlement and given a two-year prison sentence (suspended and later reduced to 18 months). Hwang has subsequently begun to rebuild his reputation with animal cloning work, but he has never regained his previous position. Similarly, He Jiankui's career needs to be ruined—not necessarily forever, but for a long, long time.

How should science accomplish this? Colleagues should shun him, journals should refuse to accept papers where he is an author, funders should forsake him. He needs to be on publicly announced blacklists, at the very least by journals and funders. And leaders of science need to take the lead in announcing this and in encouraging others to do the same.

Of course, collective ostracism, particularly coming from official or semiofficial leadership, could descend into the abyss of McCarthyism or even Stalin-era Lysenkoism. Individual scientists should decide, based on their own conscience, whether to have anything to do with He. I would encourage them to reject any contact with or overtures from He, based on what is already known. The presidents of the National Academies in the United States and their foreign equivalents, and the directors of the National Institutes of Health and the National Science Foundation and their foreign equivalents, while not pressuring scientists to avoid He, should make it clear that they approve shunning of He, pending further light on the situation. Journals should take the same position. Funding agencies, particularly governmental ones, may have a harder time ignoring applications before an official determination of He's guilt, but they should at least explore their legal powers to do so.

I do not recommend at this point that the US Academies, federal research funders, or foundations that support research perform their own investigation of He's actions. (Although investigations could well be necessary for He's collaborator from Rice University, Michael Deem). But these groups should be alert to final determinations coming from Chinese authorities investigating the situation. Some steps have already been taken against He: his funding has been canceled, and he has been fired from his faculty position. Chinese sources have implied that he will likely face criminal charges. Additional Chinese criminal or civil findings against him should be the basis for formal disqualification or other "blacklisting," at least as long as those determinations are credible. Perhaps, someday, a long life of repentance and good works by He might justify science in readmitting him into its ranks—but not soon, both for his own demerits and, more important, to discourage would-be emulators.

Creating disclosure

A harder question is raised by all the academics who had hints, or direct knowledge, of what He was doing, but said nothing. This list includes at least the scientists Matthew Porteus and Stephen Quake at Stanford; Mark Dewitt at Berkeley; Nobel prize winner Craig Mello at the University of Massachusetts; and He's collaborator, Michael Deem, at Rice. It also includes father-and-son ethicists William Hurlbut at Stanford and Ben Hurlbut at Arizona State University. Each has said that he had conversations with He about human embryo gene editing. Each has said that he discouraged He from doing it. Several have said that they suspected he might be doing it anyway. A few have said they actually knew about the pregnancies some months before the babies were revealed. Not one of them disclosed his knowledge in advance, to anyone.

I think they should have. But the word "snitching" conveys some of the difficulties of insisting on disclosure. Informing on others is sometimes socially required, while at the same time often being socially repugnant. From siblings, to high school students, to employees, informing the authorities about a colleague's misbehavior will often get you labeled as a snitch, even a "dirty snitch."

In addition to this basic social conditioning, conventions of confidentiality in science are important for allowing colleagues to communicate without fear of being scooped. Both peer review in publications and review in grant applications typically include strong confidentiality requirements, such as the destruction of any paper or electronic copies of the submitted article or the grant application. That internal code of confidentiality presumably leads to more discussion and cross-fertilization of ideas—and better research. Destroying it could slow scientific progress.

More concretely, scientists who snitch will almost certainly ruin their relationship with the snitched-on

colleague. Similarly, pediatricians who in good faith and in response to strong state laws report parents as potential child abusers will often lose those parents and their children as patients. Informing scientists might find themselves sued, successfully or not, for libel, slander, and various other offenses. If the snitch is a competitor, as will often be the case, tortious claims might even be plausible. And the scientists who report may incur broader social costs from other colleagues and potential collaborators who shun them as snitches.

Against the backdrop of this social conditioning and the valuable conventions of confidentiality, should the scientists aware of He's activities have disclosed their conversations and suspicions? And if so, to whom?

This is not a new question, to science or generally. It is not even new in discussions of the He affair: an editorial in the journal *Science* by the presidents of three national academies called for "an international mechanism that would enable scientists to raise concerns about cases of research that are not conforming to the accepted principles or standards."

This question has arisen before in the biosciences with respect to so-called dual-use technologies, those that could be used for good purposes or for evil ones, such as biological warfare. It also comes up in more routine situations where someone is aware of wrongdoing and we as a society want to encourage or protect their whistleblowing. *Qui tam* statutes, giving whistleblowers some of the proceeds of suits against wrongdoers, date at least as far back as the Civil War. Their use has continued and expanded in recent years, especially in cases where fraud against the US government is alleged. Sometimes failure to snitch on illegal activity is itself a crime, especially under specific statues relating to child abuse and elder abuse.

The He affair is simply the most recent example of why science should think hard about encouraging, or even requiring, scientists to inform *someone* of their concerns about suspect research. I am largely convinced that such an obligation should be created. But the details are important, and those are tricky to get right.

What would be the obligation? To disclose behavior you believe to be illegal, or is "unethical" enough? Is this a binding legal or ethical obligation or a guideline or aspiration? Do you have to be certain of the other's misbehavior, to have "clear and convincing evidence," or to have a "preponderance of the evidence," or just to have "reasonable suspicion"? What kinds of things should be reported? Plagiarism? Inappropriate authorship credit or order? Minor unapproved changes in a human subjects protocol? Dangerous work? Unethical work? Illegal work?

Then we hit the question of whom to tell. At least one of He Jiankui's confidants, Matthew Porteus, has said that he thought about telling someone about He's likely plans, but he did not know where to go. This is a real problem, especially when the two scientists are not in the same institution. When they are at the same university, a word to the relevant ombudsperson, department chair, dean, research vice president, or president might do the trick. But how would, say, Stanford professor Porteus go about contacting someone at China's Southern University of Science and Technology, where He worked? It is not helpful to tell people to gather up their courage and take action unless you tell them where and how to report the misbehavior of colleagues.

We could create "scientific snitching" bodies. They could be located in academic institutions, in funding bodies, in national governments, or even in some kind of international organization. Scientists should be told they have a duty to report to this entity some kinds of illegal, unethical, or dangerous research. We could even give immunity from lawsuits for those who report when they act in good faith.

Perhaps, someday, a long life of repentance and good works by He might justify science in readmitting him into its ranks—but not soon, both for his own demerits and, more important, to discourage would-be emulators.

But we also should spare a moment's thought, and pity, for the people who receive these reports. Some of the reports will be from disgruntled coworkers or jealous rivals or from the apparently mentally ill. How much chaff will need to be sifted to reveal how little grain? And who in the world would want that job?

At this point I am not sure exactly what should be done, but I am convinced that science needs to think hard about encouraging internal reporting of dangerous, unethical, or illegal research. The alternative may well be ham-fisted external requirements, or yet more loss of trust in the beneficent motives and results of science—or both. We need further study and thought on the details. We can examine precedents, such as requirements for medical professionals to report their patients for abuse and colleagues for practicing while impaired. Academic honor codes provide other useful precedents. The National Academies, or some similar group, should convene a committee to study the feasibility of such a reporting requirement and, within a

short time, report with recommendations on whether and how to make it happen.

Expressing humility

The He affair fed public concerns about mad, bad, and rogue scientists. Whether or not one ultimately concludes that He Jiankui violated Chinese laws, criminal or otherwise, he *was* a rogue scientist. He proceeded secretly to do something that he knew, or should have known, would be widely condemned. He allegedly committed fraud to do so, at least according to official reports from Chinese authorities. He's actions led many in the public to worry that scientists were pursuing their schemes with no regard for the law or for the opinions of their fellow citizens, citizens who were largely footing their bills. Science needs to make clear that it cannot, will not, and does not want to pursue research that is not acceptable to its society.

Before the He affair, scientists' statements about human genome editing openly acknowledged the importance of public opinion. A March 2015 article in *Science*, many of whose authors became members of the organizing committees of the International Human Genome Editing Summits, said we should "strongly discourage, even in those countries with lax jurisdictions where it might be permitted, any attempts at germline genome modification for clinical application in humans, while societal, environmental, and ethical implications of such activity are discussed among scientific and governmental organizations."

The organizing committee for the first summit, in December 2015, said in a concluding statement: "It would be irresponsible to proceed with any clinical use of germline editing unless and until (i) the relevant safety and efficacy issues have been resolved, based on appropriate understanding and balancing of risks, potential benefits, and alternatives, and (ii) there is broad societal consensus about the appropriateness of the proposed application."

A report issued in February 2017 by the US National Academies of Sciences, Engineering, and Medicine (NASEM) said: "With respect to heritable germline editing, broad participation and input by the public and ongoing reassessment of both health and societal benefits and risks are particularly critical conditions for approval of clinical trials."

In the United Kingdom, the Nuffield Council on Bioethics, an independent body that assesses novel bioethical questions, issued a report in July 2018 that said: "We recommend that before any move is made to amend UK legislation to permit heritable genome editing interventions, there should be sufficient opportunity for broad and inclusive societal debate."

What all these findings have in common is the need for public buy-in—at least acceptance if not full approval or consensus—before proceeding with human germline genome editing. At the second international gene-editing summit, held in 2018 in Hong Kong, where He revealed his work, David Baltimore, chair of the summit organizing committee, initially struck the right note. Immediately after He's appearance, Baltimore said, forthrightly, "There has been a failure of self-regulation by the scientific community because of a lack of transparency." And, indeed, the organizing committee's concluding statement reiterated Baltimore's condemnation of He.

But there were disturbing off-notes, both in the official concluding statement and in individual statements from prominent scientists. The organizers' concluding statement said:

> The organizing committee concludes that the scientific understanding and technical requirements for clinical practice remain too uncertain and the risks too great to permit clinical trials of germline editing at this time. Progress over the last three years and the discussions at the current summit, however, suggest that it is time to define a rigorous, responsible translational pathway toward such trials.
>
> A translational pathway to germline editing will require adhering to widely accepted standards for clinical research, including criteria articulated in genome editing guidance documents published in the last three years.
>
> Such a pathway will require establishing standards for preclinical evidence and accuracy of gene modification, assessment of competency for practitioners of clinical trials, enforceable standards of professional behavior, and strong partnerships with patients and patient advocacy groups.

The concluding statement also called for "continued international discussion of potential benefits, risks, and oversight of this rapidly advancing technology." It did not, however, say that a "broad societal consensus" would be necessary before starting clinical trials. And it did not say that before such trials start, "there should be sufficient opportunity for broad and inclusive societal debate." This statement could easily be read as: "There are a lot of technical things scientists need to figure out before this can be done. The public should have a chance to comment, but they will not make the decisions. We will."

This impression was abetted by some unfortunate statements alluding to the inevitability of human germline editing. George Daley, a member of the organizing committee, one of the major speakers, and the dean of Harvard Medical School, told the summit: "I want to suggest that I do think it's time to move forward from the prospects of ethical permissibility to start outlining what an actual pathway for clinical translation looks like. What would be the regulatory standards that a group would be held to in order to bring this technology forward?"

Daley's regulatory standards did not expressly include a societal consensus, or even social acceptance. He made a few bows toward society, but one could quite easily hear in his comments that scientists should, and would, be the ones to figure out when, and how, this new technology will be used. *Science* subsequently quoted Daley as saying, "We have to aspire to some kind of a universal agreement amongst scientists and clinicians about what's permissible.… Those who violate those international norms are held out in stark relief." At no point did he invite the public to contribute to this "universal" agreement.

My complaint is not that what the organizing committee or Daley said was wrong, but that they had a failure of omission. They did not say, let alone trumpet, the crucial need for public acceptance before anyone should use genome editing technology to make babies. At a time when rogue scientists, or science itself, is being blamed for ignoring the public, its high and mighty representatives should expressly say the following: "Science is part of society. The decision to use this technology belongs in part to scientists, but ultimately to societies."

That, of course, is a truism. If a country makes the use of genomic editing technology illegal—as many have, including (effectively) the United States—then work cannot proceed there. But the He affair marked an especially important time for science to say this, openly and clearly. The primacy of public acceptance should have been the first sentence of any reaction by scientific leaders to He's work. Instead, it was largely absent. And this, I fear, was a self-inflicted wound.

Personally, I think that the case for germline editing, if proven safe, is strong in a few applications and weak (but not trivial) in some others. But demanding social acceptance before using it to make babies is both legally and politically right. And science would benefit if its leaders made it crystal clear that they accept, and in fact agree with, that demand. Science cannot exist, let alone thrive, without the continuing financial, legal, and political support of the societies in which it works. Its leaders need to say so: early, often, and loudly.

One other aspect of science's reaction to the He affair deserves mention. After this event—and after the first summit, the NASEM report, and the Nuffield Council report—some people called for a formal moratorium on human germline gene editing. This generally is an unhelpful kind of symbolic politics. A moratorium is defined as a "temporary prohibition of an activity." The earlier statements, now called insufficient, said germline editing of babies should not then be done—in effect, a moratorium. Indeed, most countries where this work could easily be done prohibit it, with bans that are not expressly temporary. When the work is already illegal in the United States, the United Kingdom, most of Europe, and (now apparently) China, what does a call for a moratorium add?

If those calling for a moratorium are looking for a binding enforceable international agreement, with enforceable and enforced teeth, good luck to them. That path would be highly uncertain even after years of work. On the other hand, if those calling for a moratorium seek something along the lines of the landmark 1975 Asilomar Conference on Recombinant DNA—a consensus statement from the scientific community—that is effectively what the various articles and reports have done. They have repeatedly said "human germline genome editing should not be done until X, Y, and Z and we do not have X, Y, and Z." This is effectively a prohibition *until* those X, Y, and Z conditions are met: a "temporary prohibition of an activity" measured not in years but in conditions to be met.

To me, the calls for a moratorium are in part political theater: *We oppose this more than you do; you resist using the word moratorium; we insist you use it so that we will win*. I don't often like political theater. I prefer my politics and policies to be substantive. But these demands are also, in part, efforts by those who think science was not clear enough about heeding public acceptance to regain public trust. This is how I read a recent commentary in the journal *Nature* signed by some of the acknowledged leaders of science. I understand and agree with the impulse; I just don't see the importance of the "M" word.

When the work is already illegal in the United States, the United Kingdom, most of Europe, and (now apparently) China, what does a call for a moratorium add?

My logic leads me to conclude that science *could* call for a moratorium without changing its position, by expressly saying there should be a "moratorium" until certain conditions, which in my view must include social acceptance, are met. As the children's rhyme goes, "Sticks and stones may break my bones, but words will never hurt me." Accepting the word moratorium, carefully defined as a set of sensible necessary preconditions, may well be a good tactical move, even if logically unnecessary.

He Jiankui's CRISPR'd babies are not the end of the world, or the beginning of the end of our species. But they are a challenge to the ability of science to regulate itself and to the world's trust in it. Drastic action is not needed, but some useful things should be done—and just as important, should be said.

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PETER MILLS

Three Venues for Discussing Human Gene Editing

Scientists, government leaders, and the public must all be part of the debate, and our challenge is to manage the dynamic integration of these perspectives.

Little did we know when we were writing the Nuffield Council on Bioethics report *Genome Editing and Human Reproduction: Social and Ethical Issues*, published in July 2018, how quickly our call for meticulous research, broad social debate, and the painstaking formulation of governance would be overtaken by events. News only a few months later from China that treatments led by a university researcher, He Jiankui, had produced two (soon, possibly, three) children with modified genomes upended most people's expectations of the pace, order, and context of innovation in this controversial area. Blogging soon after from the auditorium in which He presented his claims to the Second International Summit on Human Genome Editing, held at the University of Hong Kong in November 2018, I suggested that his intervention had reset the initial conditions for the innovation of heritable genome editing and left scientists, policy-makers, and others scrabbling to reinvent the future. Now, a few more months on, it's worth taking stock of where we are.

First, though, some context. *Genome Editing and Human Reproduction* is the Nuffield Council's second report on genome editing. In the first, *Genome Editing: An Ethical Review*, published in 2016, we observed how it was a "distinctive consideration relating to genome editing… that it potentially brings 'basic' biological research and translation to clinical treatment into closer conjunction." One reason for this is that the distinction between research and treatment here does not so much depend on further, technically exacting steps in a developmental pathway, but on other circumstances and choices. It is rather like the distinction between therapeutic and reproductive cloning, which, 15 or so years ago, allowed people with grave misgivings about the potential

uses of that technique to find an uneasy entente with researchers exploring human somatic cell nuclear transfer in human embryos. From the point of view of embryology, the difference is undetectable; it consists, essentially, in whether the reconstructed embryo is subsequently transferred to a woman. Ironically, when I first heard of He's claims I was inclined to dismiss them, recalling how the claims of rogue embryologists to have cloned human beings always melted away before demands for proof. On the eve of big international conferences, in the intoxicating attention of global media, one hears many unfounded rumors and hyperbole. People get jittery. In the case of human cloning, the entente seems to have held, if only because it is hard to imagine why anyone (except, perhaps, the adherents of an obscure extraterrestrial cult) would actually want to carry it through. Not so, apparently, with genome editing.

Pause here for a minute. I want to acknowledge a point that has been made very widely: there are no pressing clinical indications for the use of genome editing in human reproduction. For a start, in almost no cases of heritable genetic disease are there no existing alternatives to achieve the aims of the intervention (or aims that are reasonably close to these). This would make it very hard for any genome editing innovation to meet a standard of proportionality. More important, though, if we want to give proper attention to what is at stake morally with the use of these technologies, is the need to understand these aims. By this I do not mean trying to imagine or penetrate the private motives of any individuals purposing to use the technologies, but rather to understand the technologies' proper modalities.

To be clear, then, the use of genome editing in human reproduction is not a therapeutic intervention (or is so only obliquely). Since the future person does not exist prior to or independently of the conditions in which their conception is brought about, they cannot be being treated for an existing condition. What is at stake in the use of genome editing is bringing about the birth of a human being with one set of genetically conditioned features rather than another set. The important moral question is, therefore, about which of these features, among those for which the prospective parents might have a preference, is a good reason to use the technologies available. Good reasons might include having a genetic connection with both parents and securing the absence of a specific heritable disease. Or they might not.

I would argue that whether genetic connectedness or the avoidance of disease count as good reasons to use genome editing technologies may depend as much on the circumstances of the intervention as on the ontology of the condition the intervention is intended to avoid or secure. Thus, the desire to have children with inbuilt resistance to HIV—the purported reason for He's genome editing—could *conceivably* be a good reason to use genome editing in *some* imaginable conditions. I would maintain, though, that it did not count as a good reason in the conditions that obtained in China in 2018. And the knock-down argument for why it was not a good reason in those conditions was that those conditions included substantial uncertainty about the iatrogenic, or care-induced, risks associated with the procedure. There's undoubtedly still a long way to go before this is likely to change—and no certainty that it ever will. Nevertheless, having genetically related children without genetic disease is evidently seen as a very important reason to pursue it, one that is implicitly, but very widely, socially endorsed, judging by the buoyancy of the in vitro fertilization industry.

It is only when we have understood the aims of the intervention clearly that we are able to consider how these aims should be valued. The point I want to make, however, is not a point about the conditions of *innovation* but about the conditions of *diffusion* of genome editing. The reason we, collectively, need to think about genome editing in human reproduction is not that it answers a pressing unmet need; the reason we need to think about it is that it is a potentially transformative technology. The important question is not "why do we need it?" but, once we have it, as we one day very likely will, "what might we do with it?"—which leads to the inevitable normative question "what *may* we do with it?" The diffusion of genome editing will not depend on it being "necessary" for us to have genome editing but on it delivering a valued outcome as well as or better than incumbent technologies or having desirable features that those incumbent technologies lack.

To resume. What made it more likely that genome editing would be applied in human reproduction is, as we said in our 2016 Nuffield report, the greater accessibility and facility of the genome-editing tool CRISPR-Cas9 than previous techniques for achieving genetic modification in offspring. And what *this* made more likely was that it would be used by someone in the scientific demimonde, someone on the fringes, not strongly socialized into the global scientific elite, not inculcated with or strongly attached to recognized norms and conventions, perhaps even oblivious to them. This is perhaps one of the weaknesses of analogies to the 1975 Asilomar Conference on Recombinant DNA, which has become emblematic of effective scientific self-regulation. Then, it was just about possible to gather everyone who might be in a position to deploy recombinant DNA technologies, along with their camp followers, into a single conference center on the California coast. Not so with genome editing in 2018.

Quest for a unified approach

It has been something of a mission to formulate a unified approach to the international governance of genome editing, to bring everyone into a single tent. Although there have been many initiatives on the part of scientific bodies in many parts of the world, the preeminent sites of debate have been the two international summits in 2015 and 2018, organized

under the aegis of the US National Academies of Sciences and Medicine, the United Kingdom's Royal Society, and the Chinese Academy of Sciences (on the first occasion) and the Academy of Sciences of Hong Kong (on the second). The salient features of the emerging approach to governance have been a principle of separation and a principle of order. These consist, first, in the affirmation that there is a clear and meaningful distinction between basic science, on one hand, and translational research and any potential movement into clinical use, on the other. This separation also implicitly recognizes a distinction between the role of researchers and the business of science relative to the business of innovation. Second, the steps between research and innovation are set out in a determinate order of priority, with elite scientific consensus as the gatekeeper. This does something to shore up the nominal distinction that the emerging technologies of genome editing intrinsically disturb.

The claims that the researcher He had transgressed this separation and circumvented this orderly process were traumatic to the self-conception of the scientific community. The reaction at and after the second summit is worth reflecting on. Of course, He's intervention was repudiated as something no responsible researcher would do. His choice of indication, his technical approach, and his clinical conduct were all denounced. In fact, He's presentation at the University of Hong Kong (just down the road from his erstwhile place of work in Shenzhen) was dramatized in the manner of a confession, and he was summarily anathematized at the summit and in the scientific and popular press.

There is much still to be understood about why He was not dissuaded from his course; about the disinfection of the trail of associations that He left with advisers and collaborators in the United States, China, and elsewhere; about his business interests and the involvement of partners and funders; about the reasons for his choice of indication; about his clinical conduct; and about the response of Chinese authorities to his work and the international reaction. The fact that He was, until that moment, a marginal figure will not be contradicted by anything we may discover about whatever éminences grises turn out to have supported, facilitated, or encouraged his ambitions, whether by commission or omission. But if rumors circulating are true that He has been jailed in China and is potentially facing severe penalties, the distribution of responsibility and the question of whether he is a villain or a scapegoat are important matters. And we must not forget the families and, in particular, the two or three children at the center of all this. For their sake, let me emphasize the recommendation of our 2018 Nuffield report that governments take active steps to affirm that people whose genomes have been edited should be entitled to the full enjoyment of human rights. And let me express the hope that they put this earnestly into practice where these families are concerned.

Here, however, I want to make a couple of brief points about the international governance of reproductive genome editing. The organizing committee's conclusions at the second international summit represented a notable shift from the position that emerged from the first summit. One feature of the altered approach is the shift of emphasis from one kind of regulatory distinction to another. It is as if the ideal of the separate protected space of basic research has been set aside as the primary regulatory concept in favor of the idea of the responsible pathway. The pathway, once defined, is supposed to create a visible, verifiable distinction between those who follow it and those who do not: anyone who is not on the pathway "steps out of line" and is "out of order."

This pathway, the Royal Road, leads out of the enclave of basic science and into the wider world. This raises the stakes, however, because if the ideal distinction is set aside, questions must arise about how far the public interest that is thereby awakened reaches back along the pathway toward its origin. This interest is not new, nor had it been suspended as a matter of right or indulgence, but only held in abeyance. It is as if He's intervention has "broken the fourth wall" of the laboratory and put the conduct of science directly in dialogue with the wider public realm. As a consequence, the notion of "responsibility" in play no longer refers to scientific norms, but rather to broader social norms (or, rather, the way that the subset of scientific norms embedded in broader norms becomes more apparent). A consequence of the events of Hong Kong is that genome editing became a publicly salient phenomenon, and one called to account by the law of the land rather than the norms of scientific research.

> The important question is not "why do we need it?" but, once we have it, as we one day very likely will, "what might we do with it?"—which leads to the inevitable normative question "what may we do with it?"

A second shift in the official concluding statement at the second summit was to sideline "broad societal consensus," which had been a key feature of the first summit statement. This, however, now appears all the more relevant to the definition of a responsible pathway, because "responsible" no longer means only (to quote from the first summit's organizing committee) resolving "the relevant safety and efficacy issues…, based on appropriate understanding and balancing of risks, potential benefits, and alternatives" but also taking account of

"broad societal consensus about the appropriateness of the proposed application."

The need for very broad consensus has been reasserted by a group of prominent researchers in the March 13, 2019, issue of the journal *Nature*. Their article ("Adopt a moratorium on heritable genome editing") proposes a voluntary agreement between nations not to approve any clinical use of germ line editing for a defined period, during which they should work toward the establishment of an overarching international framework.

This proposal serves as a counterweight to the position of the summit committee and, it has to be said, to the National Academies 2017 report *Human Genome Editing: Science, Ethics, and Governance*. This line is much more characteristic of most European and international responses, such as those issued in 2015 by the Council of Europe and by UNESCO's Intergovernmental Bioethics Committee. They enjoin that no state should move ahead unilaterally, pending international dialogue on the acceptability of doing so. Perhaps this kind of approach is a consequence of European human rights traditions and systems of civil law in which such strictures are grounded. Notable in this matter, for example, are the mandates enshrined in the Council of Europe's Convention on Human Rights and Biomedicine (the Oviedo Convention), which permits modifications to the human genome only for preventive, diagnostic, or therapeutic purposes and only if their aim is not to introduce any modification in the genome of any descendants, and which is binding law in 29 countries. The basic difference of approach can perhaps be glossed as the difference between leadership and consensus building.

Governance as ecology

In my presentation to the summit in Hong Kong (and elsewhere), I have suggested that we should approach international governance through the dynamic relationship among three venues in which discourses on science and technology are played out. This process may be characterized as "geo-ethics" (by analogy to geopolitics and in contrast to globalizing ethical imperialism).

The first venue may be called (following Michael Polanyi, polymath brother of the economist, Karl) the *Republic of Science*. It is, broadly, enacted in international scientific conferences and professional societies, articulated through a collective research program and structured by a dominant theoretical paradigm. The denizens of this venue are largely the participant list of the international genome editing summits. They play an important role in the education and socialization of future generations, but their primary authority relates to technical standards. This means relatively narrow questions of safety and efficacy, recognizing that even the question of what is an "appropriate understanding and balancing of risks, potential benefits, and alternatives" exceeds this competence. This is not to say that scientists, like others, do not have an important role to play in moral discourse, but as the German philosopher Immanuel Kant memorably averred, when they participate in these public debates, they have no special authority. They are a "public" among others.

The second venue, which may be described as the *Halls of Justice*, is that of international governance, instituted mainly in intergovernmental organizations (such as UNESCO and the Council of Europe). It works ostensibly through the elaboration of legal prohibition and the negotiation of "margins of appreciation" that take account of international ethical differences, although it is a mistake to think that the black letter of the law is its main purpose. Its practical role is to provide a venue to explore agreements and differences using certain principles as a framework for discussion, to weave together an international community that is an essential condition for international cooperation and coordinated action.

The third venue is that of the *Public Sphere,* that of ethics (broadly understood), which explores values and maps contours of possible consensus and conflict within particular social, cultural, and political conditions. It is here that there is a need for social processes that elicit the public interest while attending to voices of dissent, providing opportunities to represent differences of value and vision as a continual critique of orthodoxy in the context of the emerging socio-technological conjuncture. This is the "broad and inclusive public debate" that we call for in our 2018 Nuffield report. Initiatives such as the Global Observatory for Genome Editing (emerging from a 2016 meeting at Harvard University) can offer crucial visibility to the third venue, which, because it lacks formal institution, is always at risk of erasure.

We can recognize certain sorts of pathologies that come from the dynamics and imbalances of power among these three venues. For example, ignoring the third venue can lead to elitism; ignoring the first, to populism. The task, as I see it, is to bring these different discourses together. I do not think that there is a single site for this, some ideal Estates-General, or one that is not structured to favor asymmetries of power and knowledge, but I do think that at a global level, the circulation of people, ideas, and information between these venues can provide a vector for critical reflection. This is why we should support and attend to cross-cutting initiatives such as the one recently established by the World Health Organization. But it is a mistake to imagine that these efforts can ever be encompassed in a single event or institution. They form a rich, dynamic ecology that must be allowed and enabled to evolve openly, inclusively, and justly, and it is the business of us all to see that this is what happens.

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FRANÇOISE BAYLIS

Human Genome Editing: Our Future Belongs to All of Us

And we should all have a say in how the technology is governed.

In late November 2018, the Chinese scientist He Jiankui ignited a media firestorm with the birth announcement of "healthy" twin girls, Lulu and Nana (pseudonyms), born following germline genome editing to provide resistance to HIV. This announcement was followed by swift and nearly unanimous condemnation. A common theme among the critics was He's failure to respect international consensus.

As a strong and steady advocate of "broad societal consensus" as the threshold for ethically acceptable heritable human genome editing, I was intrigued by this response. What is this "consensus" whereof they speak?

A quick review of media reports and various commentaries chastising He for having violated international consensus suggests considerable equivocation about the scope and meaning of consensus. Some commentators referred to a perceived political consensus, others intuited a somewhat amorphous scientific consensus, and a few others complained of a failure to respect the call for broad societal consensus issued in December 2015 at the International Summit on Human Gene Editing.

Political consensus

Globally, the political consensus on heritable human genome editing—such as it is—inclines toward an outright ban, and if not a ban, at least a moratorium. Article 13 of the Council of Europe's Convention on Human Rights and Biomedicine (the Oviedo Convention)—the first legally binding international text designed to prohibit the misuse of biological and medical advances—stipulates: "An intervention seeking to modify the human genome may only be undertaken for preventive, diagnostic or therapeutic purposes and only if its aim is not to introduce any modification in the genome of any descendants." The Oviedo Convention, opened for signature in 1997, is legally

binding on the 29 countries that have signed and ratified it. In December 2015, on the occasion of the international gene-editing summit, the Council of Europe issued a press release reminding the world of the scope and import of Article 13.

A few months earlier, in October 2015, at a pre-conference in preparation for this summit, the UNESCO International Bioethics Committee (IBC) released the *Report of the IBC on Updating Its Reflections on the Human Genome and Human Rights*. This update called on states and governments to "agree on a moratorium on genome engineering of the human germline, at least as long as the safety and efficacy of the procedures are not adequately proven as treatment."

If we look beyond international statements to the international regulatory landscape, it appears that heritable human genome editing is mostly forbidden by law or research guidelines in those countries that have pertinent regulations. According to a 2014 survey of 39 countries, 25 countries have a legal ban in place, and four other countries have an explicit ban entrenched in guidelines. One country, the United States, has a de facto ban insofar as it is not possible to proceed with germline genome editing for reproductive purposes because of provisions in the Consolidated Appropriations Act. The act explicitly prevents US authorities from reviewing proposed clinical trials of heritable genome editing. The other nine of the 39 countries surveyed had ambiguous information.

Thus, if there is a political consensus of any kind, it is that heritable human genome editing should be prohibited, in which case there is little doubt that He violated the consensus.

Scientific consensus

Scientists disagree about the ethics and governance of human germline editing. Some scientists favor a moratorium; others want a pathway forward. This difference in perspective is not limited to genome editing, but also applies to technologies that aim to change the composition of mitochondrial DNA.

Until recently, there was agreement among members of the international scientific community that human embryos genetically manipulated in vitro should not be used to initiate a pregnancy. But then the scientific community in the United Kingdom broke ranks and spurred their government to make legislative changes to explicitly permit the transfer of some types of genetically manipulated embryos. In 2015, the UK Parliament adopted the Human Fertilisation and Embryology (Mitochondrial Donation) Regulations. In December 2016, the UK's Human Fertilisation and Embryology Authority approved the use of mitochondrial donation to eliminate mitochondrial diseases transmitted through mitochondrial DNA.

Prior to this later action, news broke in September 2016 that a child conceived following nuclear genome transfer (also known as mitochondrial replacement and "three-person IVF") had been born in Mexico in April 2016. The embryo was genetically modified in the United States at the New Hope Fertility Center in New York. The embryo transfer and birth occurred in Mexico to avoid violating US federal legislation. At the same time, a child was said to have been born of this technology in China.

In 2017, there was another such birth in Ukraine at the Nadia Clinic in Kiev. This time the clinician-researcher used pronuclear transfer instead of maternal spindle transfer, and the goal was to treat infertility, not to avoid mitochondrial disease. Since then, there have been additional births in Ukraine and, in January 2019, a first pregnancy resulting from a Spanish-Greek collaboration was announced. As yet, there are no births following nuclear genome transfer in the United Kingdom. Today, it is not clear what the international scientific consensus on heritable modifications is (or might be). It is legal in the United Kingdom to perform nuclear genome transfer (and make heritable modifications) to treat mitochondrial disease. And in some jurisdictions this is a business opportunity for the treatment of infertility.

As concerns germline genome editing, the most prominent science policy documents are the 2017 US National Academy of Sciences and National Academy of Medicine (NASEM) report *Human Genome Editing: Science, Ethics, and Governance*, and the 2018 Nuffield Council on Bioethics report *Genome Editing and Human Reproduction: Social and Ethical Issues.* Both of these reports effectively conclude that heritable human genome editing "should be permitted" under certain circumstances. The guiding principles and the stipulated conditions enumerated in these reports vary considerably, however.

The NASEM report variously affirms that it would be ethically appropriate to proceed with germline genome editing "for serious conditions under stringent oversight," "for compelling reasons under strict oversight," and "for compelling circumstances subject to comprehensive oversight." The report includes seven overarching principles—"promoting well-being, transparency, due care, responsible science, respect for persons, fairness, and transnational cooperation"—which are said to inform a 10-point "robust and effective regulatory framework."

The Nuffield Council report endorses two cardinal principles for permissible heritable genome editing: the welfare of the future person, and social justice and solidarity. It concludes that uses of the technology could be ethically acceptable if they are "intended to secure, and are consistent with, the welfare of a person who may be born as a consequence," and if they do "not produce or exacerbate social division, or marginalize or disadvantage groups in society." The report calls for "a legitimate and effective regulatory procedure" subject to "broad and inclusive societal debate."

Although there are important differences between these two reports, clearly He did not satisfy the conditions set out in either of them. Evidence of promoting well-being, or welfare of the person, was absent. Transparency and transnational cooperation clearly were lacking. Serious questions about due care and responsible science have arisen. As well, there are serious doubts about He's respect for persons, fairness, and social jus-

tice. And for those scientists who would have the consensus be a moratorium—He's actions would most certainly be in violation of this.

Societal consensus

At the close of the 2015 International Summit on Human Gene Editing, the organizing committee issued a concluding statement that included an elegant ethics framework. The committee affirmed: "It would be irresponsible to proceed with any clinical use of germline editing unless and until: (i) the relevant safety and efficacy issues have been resolved, based on an appropriate understanding and balancing of risks, potential benefits, and alternatives, and (ii) there is broad societal consensus about the appropriateness of the proposed application."

In learning of He's experimentation and the birth of the world's first gene-edited humans, Feng Zhang, a researcher who helped develop the gene-editing CRISPR technology that He used, wrote: "In 2015, the international research community said it would be irresponsible to proceed with any germline editing without 'broad societal consensus about the appropriateness of the proposed application.'" Similarly, David Baltimore, the chair of the international summit, affirmed: "It would be irresponsible to proceed with any clinical use of germline editing unless and until the safety issues have been dealt with and there is broad societal consensus."

Despite these clear strong statements in support of "broad societal consensus," the concluding statement issued by the organizing committee for the Second International Summit on Human Genome Editing, held in November 2018, makes no mention of this, but rather calls for a "rigorous, responsible translational pathway." This call is consistent with the 2017 NASEM report, and might be consistent with the 2018 Nuffield Council report, but most certainly is not consistent with the 2015 summit statement. And yet, prominent scholars refer to the 2015 statement as the international consensus, even after the publication of the 2018 summit statement. For example, in an article in *Nature Biotechnology* that listed 10 ways in which He Jiankui violated ethics, Sheldon Krimsky, who studies the links between public policy and technology, cited the 2015 summit statement when asserting, "A first problem is that He's work is a violation of an international consensus on if, whether, or when the editing of human embryos should be permitted." This writing suggests that there is consensus on the importance of broad societal consensus.

Others disagree. For example, R. Alta Charo, who was co-chair of the NASEM committee that issued the 2017 report on human genome editing and a member of the organizing committee for the 2018 international summit, writes: "Some critics [of the 2018 summit statement on human genome editing] weaponized the language of 'broad social consensus' used by the first summit's organizers, calling for an indefinite moratorium until such consensus could be reached, without describing what that consensus might look like. Certainly, a global consensus (by majority? calculated by polling? calculated by voting?) is simply impossible."

The suggestion here is that broad societal consensus is an unattainable ideal. And yet, the many references to He having violated international consensus belie this claim. Moreover, this perspective ignores recent efforts to address the meaning and scope of broad societal consensus. From another perspective, it is plausible that the real objection to broad societal consensus is that it threatens self-governance by the scientific community insofar as it requires sharing decision-making authority with civil society.

Process matters most

A few weeks after the 2018 summit, the presidents of the two US national academies and the Chinese academy that organized the summit published an editorial in *Science* eschewing broad societal consensus. Instead, they called for broad *scientific* consensus. They acknowledged the importance of forging a broad agreement that would include "not only the scientific and clinical communities, but also society as a whole." But the agreement they referred to was not agreement about whether to proceed with heritable modification, but rather agreement on how best to do so—that is, what criteria to put in place for proceeding with human germline genome editing.

It is important to educate and to engage the public in discussions about the ethics and governance of heritable human genome editing. It is also important, however, to move beyond education and engagement to empowerment. This starts with setting aside what the editor of *Nature* called "the assumption that future germline editing is a foregone conclusion." Instead of trying to assuage the public with assurances that heritable germline genome editing will proceed only subject to "strict independent oversight, a compelling medical need, an absence of reasonable alternatives, a plan for long-term follow-up, and attention to societal effects," we should be asking the world's citizens to identify their interests and ideas about how heritable human genome editing technology might makes their lives go better, or not.

As a staunch proponent of broad societal consensus, I have tried to explain that this is not about unanimity, but that it also doesn't collapse into majority rule. I have also made the point that what matters (and perhaps matters most) with broad societal consensus is the journey or the process. As people strive for consensus, they work together differently (some would say more productively) than is the case when some inside an inner circle overtly wield power and others on the outside clamor to be heard.

My bottom line is that the human genome, metaphorically speaking, belongs to all of us. We should all have a say in whether to proceed with heritable genome editing.

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MOHAMMED GHALY

Islamic Ethical Perspectives on Human Genome Editing

Religious scholars take a generally favorable position toward human genome editing research, and Gulf countries have launched several scientific efforts on the topic.

The interest in exploring the interplay of genomics and Islamic ethics took an important turn at the beginning of the 1990s, when the international Human Genome Project was declared. Since then, both Muslim religious scholars and biomedical scientists have been examining the relevant ethical questions from an Islamic perspective in addition to providing recommendations for policy-making pertinent to biomedical and genetic research in the Muslim world.

In the secular bioethical discourse, which dominates the discipline of bioethics in the West, there is a distinct class of bioethicists who lead the discussions. However, the Islamic bioethical discourse is framed by the class of Muslim religious scholars (*ulama*) who are specialists in the Islamic religious sciences. The positions adopted by these scholars are usually premised on the two main Islamic scriptures, namely the Quran (the literal word of God) and the Sunna (sayings, deeds, and approvals attributed to the Prophet of Islam). Because of the complexity and multidimensional character of the ethical questions raised by the field of genomics, Muslim religious scholars, most of whom received no training in biomedical sciences or in languages other than Arabic, sought the help of biomedical scientists to understand the biomedical aspects of the questions at hand and to gain access to the literature published in non-Arabic languages, especially English. This

interdisciplinary collaboration between Muslim religious scholars and biomedical scientists is known in the field of Islamic bioethics as the mechanism of collective reasoning (*al-ijtihad al-jama'i*).

By the beginning of the 1980s, the collaboration between religious scholars and biomedical scientists started to be the norm in Islamic bioethics, and the mechanism of collective reasoning adopted an institutionalized form through three main transnational institutions based in the Muslim world. The Islamic Organization for Medical Sciences (IOMS), established in Kuwait in 1981 and assuming its current name in 1984, has been the most active of the three institutions. In 1983, the IOMS initiated the series "Islam and Contemporary Medical Issues," which addressed a long list of bioethical questions, including those related to genomics. The IOMS coordinates with two other institutions whose interest in bioethics is rather occasional: the Islamic Fiqh Academy (IFA), established in 1977, which is affiliated with the Muslim World League and based in Mecca, and the International Islamic Fiqh Academy (IIFA), established in 1981, based in Jeddah, Saudi Arabia, and affiliated with the Organization of Islamic Cooperation.

The two-decade period between 1993 and 2013 witnessed the peak of interest in examining genomics through the lens of the Islamic ethical tradition. In addition to individual opinions expressed in works written by religious scholars or biomedical scientists, a large number of symposiums and conferences, which adopted the mechanism of collective and interdisciplinary reasoning, also addressed the ethical questions raised by genomics. The positions adopted by both individual Muslim religious scholars and the authoritative institutions were overwhelmingly positive. Some voices considered joining the genomic revolution not just an ethical option but even a collective duty that Muslim countries should collaboratively achieve. Some specific ethical questions, such as those related to genetic and genomic testing, received considerable attention in these discussions. Other questions, such as those related to incidental findings and genome editing, received less attention. That is why my analysis here will be based on previous discussions with relevance to gene therapy in general, as well as to other related topics within the broad field of Islamic bioethics.

Genome editing

In order to properly understand the Islamic ethical discourse on genome editing in particular, a number of preliminary points on the field of genomics in general are necessary. The mainstream position adopted by the majority of Muslim religious scholars and biomedical scientists views the study of human genes and genomes as part of man's commendable endeavor, since immemorial time, to explore human nature and to know oneself in an increasingly better and deeper way. Within this overall positive framing, research in the field of genomics, including genome editing, will generally be categorized as an ethical practice.

However, two main precautionary principles are usually raised to qualify, sometimes even overrule, this general permissibility under certain circumstances. The first principle is respect for human dignity. Thus, whenever research would undermine the dignity of human subjects (e.g., exposing them to risky and unsafe experiments or conducting research without informed consent), it will be judged as unethical. Despite their agreement on this point, Muslim religious scholars, as we shall see below, had different views on what the concept of human dignity would mean in the context of genomics and genome editing because they understood human nature differently. The second principle stresses that all scientific research, including genomics, should comply with the religious rulings and the overall religio-ethical system of Islam, namely Sharia. When specific research ventures contravene any of the values anchored in Sharia, this research will be seen as unethical, even if it is safe and does not involve risks for one's physical structure. One of the recurrent issues that Muslim religious scholars underscore in this context is respecting the marriage institution as the only channel through which family can be established. Hence, no children can be procreated without having a valid marital relationship between the prospective biological parents.

Beyond these overall points that govern the field of genomics in general, there is no one-size-fits-all moral judgment that views genome editing as a single block or indivisible whole. Judging genome editing from an Islamic ethical perspective can differ widely from one context to another, depending on a number of circumstances. Generally speaking, the ethical judgment is based on the

Because of the complexity and multidimensional character of the ethical questions raised by the field of genomics, Muslim religious scholars sought the help of biomedical scientists to understand the biomedical aspects of the questions at hand.

answer to two broad questions: what type of cells will be edited, and what is the purpose of editing?

Contributors to the scientific and ethical debates on genome editing worldwide usually make a standard distinction between editing somatic and germline cells. This distinction also has important ramifications when genome editing is approached from an Islamic ethical perspective.

In the case of somatic cell editing, the edited cells will affect only the person who has these cells, and thus the scope of possible benefits or harms will be limited. After gaining the patient's consent, rigorously evaluating potential benefits and harms, and making sure that privacy will not be violated, this type of genome editing will not raise serious ethical concerns, especially when it is used for research or treatment purposes. Humans do not "own" their bodies in the Islamic perspective, because the real "Owner" is God, who created these bodies. However, God entrusted humans with the task of "managing" or taking care of their bodies. Thus, humans can still make decision about their bodies in the capacity of God's trustees, as long as they do not violate the instructions of the Owner by exposing their bodies to unnecessary or unjustified risks. Still, some religious scholars hold that new techniques whose efficacy and safety are still not widely recognized, including genome editing, should be employed in the clinical setting only in the case of necessity, when other therapies cannot do the job.

Germline genome editing, however, does raise some ethical concerns among Muslim religious scholars. The mainstream position among these scholars is that there is no principled opposition to editing germline cells, but the majority of them are inclined to adopt a temporary precautionary position, something close to a moratorium, when it comes to using this technology for treating humans. At least for the time being, these scholars argue, germline genome editing should be halted because of issues related to safety and efficacy. Unlike somatic cell editing, germline cell editing will affect not only the person who has the cells but also his or her offspring. In the eyes of these scholars, the wider scope of possible effects and their long-term nature necessitate adopting more cautious procedures. On the other hand, these scholars found no harm in using this technology for research purposes or for trials on animals.

Two possible concerns that usually occupy a central position in secular ethical discourse on germline genome editing hardly attracted the attention of Muslim religious scholars. One of these concerns is the impossibility of gaining the consent of future generations who will be affected by editing germline cells. It seems that Muslim scholars believe that this is a nonissue because the consent of the parents should suffice. These (prospective) parents will have the position of a guardian (*wali*), which empowers them to make decisions on behalf of their children. I believe that this line of argumentation may work for decisions on behalf of one's direct children on specific issues, as reflected in the works of early Muslim jurists, but the case of germline cell editing can sometimes be drastically different from an ethical perspective, given the possible long-term consequences that can affect a long line of future generations and not just one's direct children. The other ethical concern has to do with the moral status of the embryos that will be the subject of research on germline editing. It seems this was also not a serious concern for Muslim religious scholars. Using nonviable or surplus embryos from in vitro fertilization processes was approved by Muslim religious scholars, as detailed in their discussions on stem cell research and assisted reproductive technologies. The mainstream position among Muslim scholars is that before embryos are implanted in the uterus, they do not have the moral status of a human being. That is why the scholars find it unproblematic to use them for conducting research with the aim of producing beneficial knowledge.

Muslim religious scholars are concerned, however, about gene therapy in which a reproductive cell is transferred from one person to another. Because such cells carry one's unique genetic structure, the majority of these scholars prohibit their transfer, especially between nonmarried couples, because this technique will disturb the lines of lineage. They argue that procreating children in Islam should take place only between married couples who biologically contribute to the genetic makeup of their prospective children.

For what purpose?

Although the traditional research/treatment and treatment/enhancement dichotomies are sometimes contested, these different categories can considerably affect how genome editing is viewed through the lens of Islamic bioethics. It is clear, however, that the collective bioethical deliberations within the Islamic tradition have yet to pay due attention to borderline cases where these dichotomies will be of little help in making a nuanced and rigorous moral analysis.

Genome editing for research purposes will yield the most permissive stance among Muslim religious scholars. Such scientific activity will be seen as a praiseworthy response to the call of Islam to search for beneficial knowledge ('*ilm nafi*'), which God eventually makes accessible to those who work hard to get it. To defend this position, various Quranic verses are recalled, such as "Say, 'Travel throughout the earth and see how He has originated the creation'. Then God will bring the next life into being. Surely, God has power over everything" (Q. 29:20); "And in your own selves; do you then not behold?" (Q. 51:21); and "Our Lord is He Who gave to each thing

its due shape and nature, then guided it aright" (Q. 20:50).

When genome editing moves from research to clinical application, it will be judged through the framework of medical treatment (*tadawi*). In principle, medical treatment is permissible from an Islamic perspective. In this regard, religious scholars usually quote prophetic traditions such as "O servants of God! Seek treatment because God never sent down a disease without sending down its treatment." Because of the novelty of genome editing, Muslim religious scholars add extra precautionary measures, especially the two points of safeguarding human dignity and abiding by Sharia rulings. Thus, using genome editing for immature and risky clinical purposes or for treating infertile married couples by having genetic contribution from a third person is considered unethical.

Another possible purpose of genome editing is enhancing capacities and powers in humans who do not suffer from malfunction or deficiency. Using genome editing for enhancement is much more controversial than using it for research or treatment purposes. One can differentiate between two main positions among Muslim religious scholars. The advocates of the first position see no harm in enhancing human capacities such as height, strength, speed, or intelligence. It seems that they reached this conclusion because they conceive human nature as something evolving and improvable, rather than stable and fixed. It is eventually God, they explain, who gave humans access to this new knowledge. When humans put this God-gifted knowledge into practice in a responsible and ethical way, this should be seen as a good act in the eyes of Islam. The advocates of the second position, however, argue that God created humans in the best possible form. As stated in the Quran, "Surely, We created man in the best of molds" (Q. 95:4). Human intervention should thus be restricted to the realm of treating diseases and restoring a patient to a normal health condition. This is the position that was adopted by the three key Muslin transnational institutions: the IOMS, IFA, and IIFA. They view human nature as something stable, fixed, and already perfect. Genome editing for enhancement purposes would be a violation of the human duty, as dictated by the Creator, to safeguard the original perfection with which humans are created. According to some religious scholars, such an act will not qualify as scientific undertaking but would rather fall under the category of "tampering" (*'abath*) with God's creation.

Judging genome editing from an Islamic ethical perspective can differ widely from one context to another.

Active participation

The generally favorable attitude of Muslim religious scholars and biomedical scientists toward genetic research and therapy paved the way for the launch of large-scale genome projects in Qatar and Saudi Arabia in December 2013. Bahrain, Oman, Kuwait, and United Arab Emirates also began their own genome initiatives. The process of developing policies and guidelines on genomics is still in its infancy in these countries, with no concrete positions on how human genome editing should be regulated. With the advancement of the already existing and planned genomic projects in the Muslim world, I expect quite permissive and accommodating policies and guidelines, particularly for somatic cell research and treatment and for germline cell research.

There are also sociopolitical and cultural considerations that I see as quite supportive as well. Muslim countries in the Gulf region suffer from high rates of genetic diseases, and the cost of treating these conditions is covered primarily by the governments. These countries have a strong incentive to reduce the costs by funding research that can eliminate or alleviate the burden of genetic disease. Finally, a feeling of bitterness overwhelms people in the Muslim world when it comes to their contribution to scientific research today. The general public as well as the intellectual and political elite share an earnest desire to regain the past golden age of science in the Islamic civilization, and they see genomics as one of the promising fields that can help them achieve this target. I would advise scientists and scientific entrepreneurs to keep an eye on the Muslim world because there is a fertile soil there for human genome editing with great potential for successful collaboration.

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Recommended reading

Mohammed Ghaly, Eman Sadoun, Fowzan Alkuraya, Khalid Fakhro, Ma'n Zawati, Said Ismail, and Tawfeg Ben-Omran, *Genomics in the Gulf Region and Islamic Ethics: The Ethical Management of Incidental Findings* (Doha, Qatar: World Innovative Summit for Health, 2013).

Mohammed Ghaly, ed., *Islamic Ethics and the Genome Question* (Leiden, Netherlands: Brill, 2019).

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KEITH KLOOR

UFOs Won't Go Away

A community of believers in extraterrestrial visitations continues to push its story, and the media and Pentagon continue to listen. Who benefits from these tales of close encounters?

In his annual performance evaluation for his job at the US Department of Defense (DOD), Luis Elizondo, a career military intelligence officer now in his late 40s, was lauded in 2016 for his ability to manage a highly classified program "in a manner that protects US national security interests on a global scale." The office Elizondo oversaw had, among other things, "identified and neutralized 6 insider threats" and "co-authored 4 national-level policies involving covert action." His work performance was rated as "exemplary." The evaluator gushed that it "cannot be overstated the importance of Mr. Elizondo's portfolio to national security."

So it must have come as a surprise to at least some of Elizondo's superiors when he departed the Pentagon a year later on a sour note. On October 4, 2017, Elizondo submitted a resignation letter—that he later made public—addressed to then Defense Secretary James Mattis, which warned that "bureaucratic challenges and inflexible mindsets" had prevented "anomalous aerospace threats" from being taken seriously within DOD leadership. There was "overwhelming evidence" of these threats, Elizondo wrote, "at both the classified and unclassified levels." He referred vaguely to "many instances" of "unusual aerial systems interfering with military weapon platforms and displaying beyond-next-generation capabilities." The letter urged Mattis "to ask the hard questions" about who else might know about these "phenomena" and their "capabilities."

Days after exiting the Pentagon, Elizondo joined a new entertainment and research company cofounded by Tom Delonge, formerly the lead singer and guitarist of the band Blink-182 and a paranormal enthusiast, who was known for spending his time between concert gigs on the hunt for unidentified flying objects (UFOs) and Bigfoot. The for-profit venture was called To The Stars Academy of Arts & Science and included former Pentagon and Central Intelligence Agency (CIA) officials, as well as several scientists contracted over the years by US intelligence agencies.

In mid-December of 2017, several months after Elizondo left the DOD, the *New York Times* reported that he had recently overseen a "shadowy" $22 million Pentagon program that investigated UFOs buzzing US military jets and installations. The aviation writer Stephen Pope called the article "borderline-sensationalist." The science journalist Jeff Wise said it "gave free rein to claims that the [Pentagon] program had found evidence of strange aircraft that flew in seemingly impossible ways."

Regardless, the story was picked up widely in the media. Elizondo, who had served as a primary source for the *Times* reporting, talked cryptically about the government's UFO program on the major news channels. His credentialed background and earnest bearing made people pay attention. Notably, the Miami native did not sound like a crackpot who had watched too many *X-Files* episodes. In fact, during his media blitz Elizondo carefully avoided mentioning the term "UFOs" or anything that might be construed as a reference to extraterrestrials. But in one instance he deviated from his careful phrasing when he said on CNN, "My personal belief is that there is very compelling evidence we may not be alone."

News of the Pentagon's UFO program continued to generate headlines as more tidbits dribbled out via Elizondo and the new company he worked for. Other high-powered members of the To The Stars Academy also began airing their

concerns about unknown, physics-defying aircraft showing up in US airspace. One of these voices was Chris Mellon, who served as the deputy assistant secretary of defense for intelligence in the Clinton and George W. Bush administrations. (In this capacity, Mellon oversaw the Pentagon's most sensitive and closely held "black" programs.) On March 9, 2018, he published an op-ed in the *Washington Post* titled, "The military keeps encountering UFOs. Why doesn't the Pentagon care?"

And so, in the span of a few months, a topic long confined to the tabloids and fringe media had become a "serious news story" as the *Post* asserted in its coverage last year, shortly after it published Mellon's op-ed.

We have all been here before

Most scientists with relevant expertise attribute UFO sightings to misperception of celestial or meteorological phenomena. Distant planets, comets, and clouds have often been mistaken for alien spacecraft by sophisticated observers. Even highly trained military and commercial airline pilots have been known to confuse atmospheric optical phenomena for mysterious flying objects.

Still, the disclosure of the Pentagon's UFO program, which officially existed between 2008 and 2012, has stirred interest on Capitol Hill. Members of the House and Senate Armed Services Committees have requested details on the program; the latter has quietly interviewed a number of the military pilots who claim to have witnessed UFOs while on training missions. Influential to this effort is Mellon, a Washington insider for decades, who left the Pentagon in the early 2000s, did a stint as Democratic staff director for the Senate Intelligence Committee, and now works alongside Elizondo at the To The Stars Academy, which bills itself as an "initiative mobilizing the brightest minds from within the top-secret shadows of aerospace, science and the Department of Defense." That placard is at the top of a company website page that sells branded T-shirts, hoodies, and other merchandise.

Several years ago, Mellon told one interviewer that there were "sufficiently well-documented" UFO cases that "warrant a scientific investigation of the phenomenon." I have recently discussed with him the merits of this claim in phone and email conversations. In one such exchange in late 2018, I shared a comment I had received from a prominent astronomer who said he was "very skeptical about the alien interpretation of UFO reports" that had been circulating in the media.

Mellon was indignant. "I did not claim the objects were alien," he shot back in an email. "Merely real, intelligently controlled and not ours—hence the need to investigate further." Then he added: "Off to Govt mtgs in DC today with people who are on the front lines of this." In a follow-up exchange later that day, he mentioned that the people he was working with felt "an urgency to engage Uncle Sam and the public from a national security standpoint."

This was also the media's recent take on the Pentagon's UFO program: that military and intelligence professionals had come forward to speak of UFO incidents that they believed should be treated as a national security matter. Several historians following this news heard an echo from the past. "What is so striking is that the rhetoric hasn't changed since the late 1940s, in ways that are stunning to me," says Kathryn Dorsch, a University of Pennsylvania historian whose research connects the rise of the UFO phenomenon to Cold War anxieties.

Greg Eghigian, a history professor at Penn State, was also taken aback after seeing the flurry of attention to UFOs sparked by the *Times* story. Like Dorsch, Eghigian studies the topic through a sociocultural lens. "When all this new stuff broke, I got déjà vu," he says.

To Eghigian and Dorsch, there are striking similarities between a central UFO narrative from the Cold War era and the one getting mainstream media attention of late. The two scholars also see notable parallels between the cast of characters that drew public attention to UFOs in the 1950s and those doing so today.

Which raises the question: Have alien-powered craft been stalking the skies since the Truman presidency, all the while remaining elusive and difficult to positively authenticate? And if so, is the "deep state" suppressing that evidence? Or might there be a less extraordinary explanation for a UFO narrative that has persisted for 70 years, ever since the dawn of the advanced aerospace age?

In the beginning

Historians trace the birth of the UFO phenomenon in the United States to an Associated Press dispatch in the early summer of 1947. The article stated that a private pilot named Kenneth Arnold reported seeing "nine bright saucer-like objects" while flying his small airplane above the state of Washington—what headline writers described as "flying saucers," thus coining a phrase that would soon become lodged in the public's imagination.

Others reported seeing similar objects (also described as "flying discs") in the following weeks and months, prompting nationwide headlines and an investigation by the US Air Force. It was an anxious time: the country was still recovering from World War II just as it was reckoning with the Soviet Union's nuclear ambitions. The flood of flying saucer reports spooked the military. Were people hallucinating, or seeing something from Moscow or Mars? Experts grasped for answers. A scientist interviewed by the *New York Time*s in July 1947 called it a "mild case of meteorological jitters" and "mass hypnosis."

But the UFO sightings kept coming in waves over the next few years. Initially, Air Force investigators thought that the objects had been "domestically launched devices such as weather balloons, rockets, experimental flying wing aircraft, or celestial phenomenon." Some investigators gave serious consideration to the possibility of extraterrestrials. But by 1949, the official Air Force position was dismissive of that hypothesis and the

military sought to downplay UFO sightings.

This angered a group of well-connected ex-military officers who would soon get the ear of the public. Perhaps the most influential voice belonged to retired Marine Corps Major Donald Keyhoe, who in January 1950 published a much-publicized article in *True* magazine titled "Flying Saucers are Real." Keyhoe slammed the military's UFO investigation and proclaimed that Earth had "been under systematic close-range examination by living, intelligent observers from another planet."

Keyhoe quickly expanded his popular article into a book with the same title. It sold more than half a million paperback copies. Several years later, he published another bestseller asserting that the Air Force was suppressing evidence of encounters between the military and interstellar UFOs.

The media seized on the public's fascination with flying saucers. In 1952, *Life* magazine published a lengthy article titled "Have We Visitors From Outer Space?" The article concluded that dozens of sightings examined by government investigators were "seemingly unexplainable." It also contained this eye-popping quote from an unnamed military intelligence officer: "The higher you go in the Air Force, the more seriously they take the flying saucers."

The impact from *Life*'s story was "explosive" and "quickly led to a dramatic uptick in UFO sightings around the country," writes Mark O'Connell in his recent book, *The Close Encounters Man*. By then, the Air Force had reopened its examination into the sightings. The newly assigned head of the investigation**,** Captain Edward Ruppelt, brought a somber, methodical approach to the effort. In Air Force verbiage, he replaced "flying saucer" with "Unidentified Flying Object," which he is said to have considered more neutral and accurate. (Of course, in due time even the term "UFO" would become shorthand for alien spaceship.) Ruppelt oversaw what became known as Project Blue Book at a period in the early 1950s when the US government was grappling with a problem it didn't fully understand.

Frustrated by bureaucratic issues and lack of support, Ruppelt left Project Blue Book after a few years and retired from the military. In a 1956 book about his experience, called *The Report on Unidentified Flying Objects,* he wrote:

> I wouldn't class myself as a "believer," exactly, because I've seen too many UFO reports that first appeared to be unexplainable fall to pieces when they were thoroughly investigated. But every time I begin to get skeptical I think of the other reports, the many reports made by experienced pilots and radar operators, scientists, and other people who know what they're looking at. These reports were thoroughly investigated and they are still unknowns. Of these reports, the radar visual sightings are the most convincing. When a ground radar picks up a UFO target and a ground observer sees a light where the radar target is located, then a jet interceptor is scrambled to intercept the UFO and the pilot also sees the light and gets a radar lock on only to have the UFO almost impudently outdistance him, there is no simple answer. We have no aircraft on this earth that can at will so handily outdistance our latest jets.

When I read this passage in Ruppelt's book, I was struck by how much it resembled what Elizondo and Mellon have said publicly about supposed latter-day UFO incidents involving the military. Both have emphasized in conversations with me the importance of advanced twenty-first century spy radar systems that they say have detected "anomalous" aircraft, aka UFOs. But getting the Pentagon to acknowledge this has been another matter, they assert. More concerning, they say, is the military's apparent lack of interest in the matter. "We cannot afford to avert our eyes, given the risk of strategic surprise," Mellon writes in his 2018 *Washington Post* op-ed. "It is time to set aside taboos regarding 'UFOs' and instead listen to our pilots and radar operators."

Perhaps the unknown objects being spotted by military radar are nothing to worry about, Mellon and Elizondo say,

A local newspaper was told by an Air Force intelligence agent that a nearby military base had "come into the possession of a Flying Saucer." This was a deliberate falsehood.

rhetorically, or maybe they are—except there's no way to know unless the Pentagon spends money and manpower to find out.

"That's the same argument Ruppelt made back in 1955 and 1956," after he retired from the Air Force, says the Penn historian Dorsch, who is writing her doctoral thesis on the birth of UFO phenomenon.

Mellon and Elizondo have also said that they are frustrated by the institutional secrecy that prevents a more concerted government investigation into the "phenomena," as they call it. This argument, too, is similar to what other media-savvy voices such as Keyhoe were saying in the 1950s, when he was president of a nonprofit organization called the National Investigations Committee on Aerial Phenomena (NICAP). Its leadership included retired military and intelligence officials, such as a former chief of the Navy's guided missile program. Another prominent member was Roscoe Hillenkoetter, who had served as the first director of the CIA, from 1947 to 1950.

These high-profile individuals gave NICAP credibility, but Keyhoe was its face. And he was a relentless, aggressive crusader; his frequent accusations that the military and CIA were hiding evidence of extraterrestrials planted the seeds of

conspiracy that would grow into a core UFO narrative that has since become a theme of UFO conventions and a multitude of books, movies, and television shows.

From Roswell with lies

This conspiracy narrative has its roots in a true historical event involving a classified military project initiated in 1947, at the dawn of the Cold War, and just as the UFO bug was sweeping the United States. Amid the flurry of sightings that year, one stood out: someone had found pieces of a "flying disc" on a ranch in Roswell, New Mexico. A local newspaper was told by an Air Force intelligence agent that a nearby military base had "come into the possession of a Flying Saucer."

This was a deliberate falsehood. So was the next official press release from the government a day later, which stated that the object was actually a weather balloon. Despite this puzzling turnabout, the incident quickly faded from headlines as the UFO epidemic spread across the country in the summer and fall of 1947. Roswell did not serve as gruel for breathless tales in the media. In fact, it wound up being little more than a footnote in UFO annals for more than 30 years.

Then, in 1980, a book called *The Roswell Incident* was published. One of its coauthors had previously written a bestseller about the Bermuda Triangle, which was a hot topic in the 1970s. *The Roswell Incident* claimed to find long-suppressed information about a crashed flying saucer and alien body that had been recovered in 1947 by the military. A UFO myth was born. It would, as one science writer later observed, launch "the modern wave of UFO crash/retrieval conspiracy beliefs." Today, Roswell is the mother of all UFO conspiracies.

The truth, however, was something called Project Mogul. Several decades ago, the US military finally acknowledged that the object found at Roswell in the summer of 1947 was, in fact, a spy balloon that contained an instrument used to monitor sonic booms from anticipated nuclear tests by the Soviet Union. Of course, given that the military's first words about the Roswell incident really were lies (not to mention the Pentagon's general reputation for duplicity, especially during the Vietnam War), it is understandable why many UFO believers are reluctant to let Project Mogul stand as the final word on Roswell.

Then there is the matter of Area 51, a remote, highly classified Air Force base in the Nevada desert that until recent years wasn't even officially acknowledged to exist. In flying saucer lore, Area 51 represents an "underworld of aliens and captured UFOs," as Annie Jacobsen puts it in her critically acclaimed 2011 book, *Area 51: An Uncensored History of America's Top Secret Military Base.* But, as she writes, "The truth is that America's most secret federal facility was set up to advance military science and technology faster and further than other foreign powers in the world."

To understand those advances in military science and technology—and how they are cloaked in secrecy and cunning misdirection—is to understand the enduring power of mythical UFO narratives.

Mixed motives

When Luis Elizondo was at the Pentagon in the late 2000s, he was asked to take over security for the Advanced Aerospace Threat Identification Program (AATIP). He had experience in technology protection, having previously worked with Boeing and its Apache Longbow helicopter, and also with Raytheon and some of its cruise missile technology. A new aerospace-related assignment made sense.

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But AATIP was different than anything he had worked on before. It was created in 2007 to study "anomalous aerospace threats," a euphemism for UFOs. His job, he explained to me, was "making sure the Russians, the Chinese, our foreign adversaries, weren't penetrating [AATIP] or developing some sort of deception campaign." He cut himself off at this point. "I have to be careful, because we can get into classified stuff pretty quick." After a brief pause, he continued: "Anytime you have a game-changing, advanced technology, your adversaries will want to know what it is, because it could be used against us. So there's this huge effort try to figure out what the other side has."

Evidently, there were security issues with the new UFO program that had to be addressed. "I knew there were counterintelligence problems that needed to be fixed," Elizondo said. "I'm kind of like the plumber that needs to fix leaks." He eventually took over the program and insists that he kept it afloat until he left in 2017, although funding officially dried up in 2012.

Whatever Elizondo learned while running AATIP seems to have convinced him that UFOs are real. And because he wasn't able to convey this to higher-ups in the Pentagon's chain of

command, he decided to quit and let the world know about the program. "That was the only way to continue the mission," he said to me just before he was scheduled to speak at a "symposium" organized by the Mutual UFO Network, an organization of UFO believers, in the summer of 2018. He was the keynote speaker, part of a featured lineup that included a former logger whose story of alien abduction was made into the 1993 movie *Fire in the Sky*.

Until he showed up at the UFO gathering, Elizondo was careful not to do or say anything that would lump him in with the Elvis-on-Mars crowd. He was mindful of the stigma attached to a subject he wanted taken seriously by the Department of Defense. But now he was the headliner at a conference titled "UFOs, Extraterrestrials, and the Future of Humanity." Why participate in that?

"I'm trying to get the conversation going," Elizondo said to me, during a wide-ranging interview in his hotel room several hours before his scheduled talk. This perplexed me. The hundreds of attendees at this conference already believed in UFOs. A number of the panels were geared for "experiencers," people who thought they had been touched in some way by space aliens. If Elizondo wanted UFOs to be treated as a national security matter, why come to venues such as this?

I thought that perhaps he was looking to attract new investors for the To The Stars Academy, which was on its way to crowdfunding more than two million dollars. There is, after all, a thriving UFO marketplace, fueled by conventions, podcasts, and popular pseudo-documentary shows such as the History Channel's *Ancient Aliens*.

Elizondo resented the suggestion (already made by others) that he was in the UFO racket. "This is not a moneymaking endeavor for me," he insisted, referring to his new company and role as a public figure speaking out about the threat posed by UFOs. (He said he refused to take a fee for his appearance at the conference.) Okay, then why did he come out from the shadows after a long, distinguished career as an intelligence officer? Why go public about a Pentagon program that had been deliberately shrouded in secrecy?

But Elizondo also resented the suggestion that he was a whistleblower, as some have characterized him. He was speaking out, he said, because he felt duty bound: "I'm doing this for the same reason I hunted terrorists in Afghanistan, the same reason I caught spies in South America, for the same reason I left the [Defense] Department—because there is a problem. We have pilots, soldiers, [radar] operators, men and woman who have seen something and in some cases are even being punished for reporting it. These are loyal Americans, people who run multimillion-dollar weapons platforms with live munitions over US cities and we don't trust them to say, 'There's something there and I don't know what the hell it is.' "

"I did not do this for frills and thrills," he said coolly. "I did it to tell the truth."

Within the conspiratorial ranks of the UFO community, there are many who wonder about that. Their suspicions about Elizondo have their roots in the story of Richard Doty, a former special agent for the US Air Force Office of Special Investigations. Some years ago, Doty came forward to say that he had deliberately given false information to numerous self-styled UFO researchers when he was assigned to Kirtland Air Force Base in Albuquerque, New Mexico, in the 1980s. Doty fed his unwitting stooges fake evidence of captured aliens and flying saucers inside top secret military bases, which breathed life into the Roswell legend. A fascinating 2013 documentary called *Mirage Men* captures the extent of his deeds—in his own words and those of the UFO researchers who interacted with him.

Whether Doty is a fabulist or true confessor is impossible to verify and still hotly debated in UFO circles; if he has misrepresented himself, he has never been charged by the US government with any crimes. But as the science writer and podcaster Brian Denning has noted:

> Much of Doty's story is believable and dovetails very well into history. The late 1970s and early 80s were the years when the F-117 Nighthawk stealth attack aircraft was still a secret, but very much operational. Soviet spies desperately wanted information about it. Armies of UFOlogists had been encamped around every Air Force installation since the 1950s, documenting, filming and disclosing their findings at conferences. The Air Force very astutely assumed that Soviets were likely to have infiltrated the UFOlogy community to see what these legions of amateur investigators had found, and sent Doty (and, we presume, others like him) to provide stories of captured flying saucers and alien ambassadors working with the US government.

Elizondo has heard the rumors about himself floated on the internet—that he is a latter-day Richard Doty. These suspicions were also whispered to me in the hallways of the UFO conference he was headlining when we first met. "No, I am not running a government disinformation campaign," he said to me when I caught up with him again at the end of the event. We talked over burgers and beers at an airport bar. For someone who had been an interrogator at Guantanamo Bay, Elizondo has a likable, disarming presence, which is a handy trait to possess if your goal is to earn the trust of those who might otherwise be suspicious of you.

We stayed in touch over the next few weeks, while I was working on a story about him for *Newsweek*. The suspicious whispers in UFO circles were getting louder. "This is a very hard path I am on and sometimes I wish I could fade off into the sunset and let someone else do this," he texted me one day. "It really sucks being judged by people who have never met you and question your credibility and motivations every step of the way. I think I very much prefer the shadows."

Trust us, we're experts

In 1966, Walter Cronkite ("the most trusted man in America") hosted an hour-long CBS special report titled *UFO: Friend, Foe, or Fantasy.* At the time, the UFO craze in the United States showed no sign of ebbing. There had been periodic waves of sightings for nearly 20 years, spawning flying saucer cults, amateur groups of zealous researchers, and a lucrative genre of sci-fi movies and books.

For his show, Cronkite enlisted a number of prominent experts, such as a young astronomer named Carl Sagan, to demystify UFOs. J. Allen Hynek, another astronomer who was a scientific adviser to the Pentagon's ongoing UFO investigation, also was featured. "To this time, there is no valid scientific proof that we have been visited by spaceships," Hynek told Cronkite. "The great majority [of UFO sightings] are balloons, meteors, satellites, aircraft seen with the sun glistening off of them, and birds," he explained. Hynek did allow that there were a very small number of "most interesting cases that intrigue me in the same way that a good mystery story intrigues me." (Indeed, Hynek eventually did come to believe that some extraterrestrial or otherworldly presence might explain those unsolved mysteries.)

After Cronkite was done with the science portion of the show, he turned to other possible explanations, such as new military technology, "strange looking crafts" that had been created by the budding aerospace industry for the Air Force. There were also other unknown craft, he added, "probably being tested in secret."

Still, public interest in UFOs could not be dimmed. Several years after Cronkite's broadcast, the Air Force contracted with the University of Colorado (CU) to convene a distinguished panel of scientists on the subject. Led by the CU physicist Edward Condon, the group concluded in 1968 after an in-depth study that there was no basis to the extraterrestrial interpretation of UFO reports and "that nothing has come from the study of UFOs in the past 21 years." The panel's voluminous report totaled nearly 1,000 pages and focused "almost entirely on the physical sciences," meaning it examined UFO sightings in the context of explainable celestial and meteorological phenomena. In 1969, a National Academy of Sciences panel reviewed the report and concurred with its finding, writing: "While further study of particular aspects of the topic (e.g., atmospheric phenomena) may be useful, a study of UFOs in general is not a promising way to expand scientific understanding of the phenomena." Pointing to these conclusions, the Pentagon announced that it would no longer investigate UFO reports.

None of this seemed to reduce the allure of flying saucers. UFOs remained a hot topic into the 1970s, as a new wave of popular sci-fi films, such as *Close Encounters of the Third Kind* and *Alien*, continued to stoke public fascination. By the late 1990s, other big UFO subthemes had been prominently introduced into pop culture, such as the abduction phenomenon and government conspiracy narrative, via best-selling books and, of course, *The X-Files*.

The continued attention was also fed by new disclosures of previously unknown government interest in UFOs by US intelligence agencies. Using the Freedom of Information Act (FOIA), dogged UFO crusaders successfully sued the federal government to unearth documents that revealed that the CIA had been periodically monitoring UFO reports and the active community of believers since the 1950s. The agency, it turned out, had even commissioned its own classified study to determine if there was any substance to any of the UFO reports. (It reached the same conclusion as the CU-led and National Academy of Sciences panels.) Of course, the revelations of the CIA's longtime interest in UFOs only reinforced the belief of many in the UFO community that the spy agency was hiding evidence of extraterrestrials.

Perhaps hoping to defuse this notion, the CIA in 1997 allowed its official historian, Gerald Haines, to publish a report explaining how the CIA's U2 spy plane and other advanced reconnaissance projects, such as the SR-71 Blackbird, had frequently been mistaken for UFOs from the late 1950s through the 1960s. Haines acknowledged that the Air Force's UFO investigators during this period had been made aware of the CIA's ultra-secret spy projects, but were told not to reveal the true cause of many of the flying saucer sightings. "This led the Air Force to make misleading and deceptive statements to the public in order to allay public fears and to protect an extraordinarily sensitive national security project," Haines wrote. "While perhaps justified," he added, "this deception did end up adding fuel to the later conspiracy theories."

Such deception might also have inadvertently contributed to the lingering distrust felt toward scientific experts by UFO believers. After all, those blue-ribbon panels in the late 1960s dismissed most sightings as optical illusions. Since then, scientists have become even more exasperated by the persistence of UFOs in the public mind. But we now know that a good number of those strange aircraft sightings were likely real—just not extraterrestrial in origin.

This larger, complex history of the UFO phenomenon is especially problematic for professionals in the military and intelligence community who have come forward of late with alarming stories of unknown "anomalous" aircraft and plead to be taken seriously.

They're back

On the afternoon of November 14, 2004, two F/A-18 "Super Hornet" fighter jets were 30 minutes into a training drill off the coast of Southern California when they were redirected by a Naval radio operator to a "real world situation." Earlier that day, the USS *Nimitz* nuclear aircraft carrier and the USS *Princeton* missile cruiser had detected more than a dozen unidentified objects on their radar screens—what the Navy

then referred to as Anomalous Aircraft Vehicles.

The F/A-18s were told by the *Princeton*'s captain to intercept the closest anomalous vehicle, which was located about 150 miles southwest of the San Diego coastline. When the pilots reached their coordinates, they spotted from an altitude of 20,000 feet a disturbance at the ocean's surface. One of the pilots, Commanding Officer Dave Fravor, reported that he saw a white oval or "Tic Tac"-shaped object about 50 to 60 feet in size moving just above the churning water.

Fravor headed down for a closer look. What happened next was "like nothing I've ever seen," he recounted in 2018 in a video posted on the internet: the object accelerated so fast that it disappeared in a blink of an eye. A pilot in the other F/A-18 has described the episode similarly; he also says he watched as the object zipped around Fravor's plane before it darted off in a flash.

Meanwhile, according to testimony from Petty Officer Gary Voorhis, who was stationed on the *Princeton* at the time of the episode: "At a certain point there ended up being multiple objects that we were tracking. That was towards the end of the encounter and they all generally zoomed around at ridiculous speeds, and angles, and trajectories and then eventually they all bugged out faster than our radars."

The entire episode, which lasted between five and seven minutes, was monitored on the *Princeton*'s Command Information Center, according to an unpublished paper that analyzes the incident, authored by a group of longtime UFO researchers, several of whom have scientific backgrounds and careers in the semiconductor and aerospace industries.

The paper reveals that in the immediate aftermath of the incident, a video of the encounter was shared and viewed widely by members aboard the *Princeton* and *Nimitz* via an internal military email system. Then, according to three witnesses of the Tic Tac episode interviewed by the paper's authors: "The communication logs, the radar data, and other associated electronic information was removed from the USS *Princeton* and a copy of the video from the USS *Nimitz*."

According to the paper, here's what happened: within 12 hours of the incident, a helicopter carrying nonuniformed personnel landed on the *Princeton.* They approached Petty Officer Voorhis, who was in charge of the ship's Cooperative Engagement Capability (CEC) system, and requested that he turn over all the ship's radar data, electronic information, data recordings. He asked for their identification, and when they refused, he told them that he needed permission from the ship's captain before complying. Shortly after that, his captain gave him the order and Voorhis relinquished all the information, which was stored on magnetic tapes.

The tapes contained crucial data that would easily shed light on the mysterious Tic Tac-shaped object. Said Voorhis to the paper's authors: "You could literally plot the entire course of the object, you could extract the densities, the speeds, the way it moved, the way it displaced the air, its radar cross-section, how much of the radar itself was reflected off its surface. I mean you could pretty much recreate the entire event with the CEC data."

After I read this, I thought back to the gist of Elizondo's beef with the Defense Department, and Mellon's complaint in his *Washington Post* op-ed, that such incidents (and others like it) "remain largely ignored and unevaluated" by the military.

That does not seem to be the case with the *Nimitz* event, unless the former airmen and sailors who spoke on the record to Robert Powell, the lead author of the paper, have concocted the aforementioned chain of events—and in coordination with one another to keep their stories straight. But here again, Powell and his colleagues, despite their bias in favor of extraordinary explanations of what happened, also did their homework. They found a 2013 Facebook page for the *Nimitz* that contains a conversation about the 2004 incident among various shipmates who served together at the time. All those on duty that day recalled it vividly in their Facebook comments; many said they were still befuddled by what they saw and why the data mysteriously disappeared.

Hard data, credible witnesses

The paper that meticulously chronicles the *Nimitz* incident is titled "A Forensic Analysis of Navy Carrier Strike Group Eleven's Encounter with an Anomalous Aerial Vehicle." Two of the primary authors, including Powell, gave a detailed presentation at a conference in Huntsville, Alabama, in mid-March of 2019, called the "Scientific Conference on Anomalous Aerospace Phenomena." The conference was organized by a group of academics, engineers, and scientists that calls itself the "Scientific Coalition for UFOlogy" (and includes scientists from NASA, the European Space Agency, and the North American Aerospace Defense Command). The group says it endeavors to take a cold-eyed approach to the UFO issue, and as such, examines only cases that have hard data and credible witnesses. "We're looking to stay neutral and build a coalition of like-minded scientists," says Rich Hoffman, who does information systems work for the US military and was the lead organizer of the event.

I attended the conference, curious to see if science would really take center stage at a UFO event. To my surprise, the panels were staid PowerPoint presentations. No talk of abductions or Big Foot; just lots of mathematical formulas from physicists about the challenges of interstellar travel and space propulsion, and clinical examinations of several incidents involving supposed UFOs, such as the *Nimitz* case.

The big draw, though, was Elizondo, who gave a talk on the opening night. He didn't offer anything new or noteworthy about the UFO program he once led at the Penta-

gon, although he did say the "effort" was ongoing. (A public affairs officer at the Pentagon has said the program expired in 2012.) Elizondo told the audience that he had remained in close touch with his successor. In fact, he said that earlier in the week he had "received a call from a friend of mine, a very dear colleague of mine, who's still at the Pentagon, who works this effort, very closely." Elizondo then paused briefly. "You can read between the lines. When I say 'is working this effort,' I don't mean the past, but actively working this. So it definitely continues. It's still going. That, too, will come out hopefully soon in a very official way."

Elizondo went on to insist that "disclosure has occurred" and that UFOs "are real." Moreover, he added, "We have also established that fact from a national security perspective. You now have people at the highest levels of the United States government and international communities of their governments finally taking this serious, applying real resources, real talent, real expertise to look at this and finally figure out what this is."

Next he addressed the elephant in the room. "Am I a spy for the CIA trying to fool people and do soft disclosure?" he asked rhetorically. "At the end of the day, who cares? You're getting the information that was squirreled away in these little secret hidden compartments. It's now coming to light."

I approached Elizondo after his presentation to say hello and see if I could get another interview with him. He was cordial and open to talking, but said that it would have to be off the record. I found that disappointing, but understandable. Since we first met nearly a year ago, he had not been pleased with critics on social media and blogs who were scrutinizing his every move and utterance. He and his UFO company were under a sharp microscope. For example, in late 2018, Elizondo had traveled to Rome to give a presentation to European UFO buffs that was videotaped and quickly posted to the internet. Skeptics found the talk littered with dubious historical claims, including a reference he made to the 1947 "Roswell incident" that suggested the real truth was still unknown. "I'm not going to speculate in this room what crashed at Roswell," he told that audience, before proceeding to cast doubt on the official explanation given at the time, as if he was unaware of Project Mogul's disclosure.

An American tradition

In his Rome talk, Elizondo also discussed a famous 1952 incident when flying saucers were reported over Washington, DC. There is no historical photo that captures the supposed UFOs, but in his talk Elizondo showed a slide that suggested one existed. "It was actually a still [image] from a CGI [computer generated animation]," says John Greenwald, a longtime FOIA archivist who discusses Elizondo in a newly published book titled *Inside the Black Vault: The Government's UFO Secrets Revealed*. As soon as this was pointed out to Elizondo on the internet, he apologized for the error on his company's Facebook page.

There are other discrepancies that have put him on the hot seat. He and his company have facilitated the release of video footage that show military pilots engaging with supposed UFOs. Several of these, including a grainy 45-second video of the *Nimitz* incident, have gone viral online, due in part to the recent media coverage that he and Mellon have received. Elizondo has insisted that the videos were declassified and released by the Pentagon in 2017, which the Pentagon denies. Even odder, a video of the *Nimitz* incident—the same one the *New York Times* embedded in its 2017 article and claimed to have received from the Pentagon—was already bouncing around on the internet in 2007.

Whatever its provenance, it is this video and others like it that Elizondo and Chris Mellon cite as compelling evidence of aerial wizardry by UFOs that pose a threat to US national security. As one might expect, an online army of eyes with many years of aviation and aerospace experience have minutely examined the videos. The crowdsourcing consensus, helpfully compiled into a detailed rundown of the incident at a popular skeptic's blog, is that the "anomalous phenomena" asserted by Elizondo and Mellon are more likely explained as sightings of some sort of classified missile or aircraft, perhaps a drone, being tested at the time.

That would make sense given the mysterious scrubbing of electronic data relating to the 2004 incident, as reported by various crew members on the *Nimitz* and *Princeton*. Perhaps the aerial phenomena around which Elizondo and Mellon seek to cast such a veil of mystery can instead be chalked up to a familiar cause of UFO sightings over the past seven decades—advanced military aircraft and weaponry that the Pentagon is trying to keep secret.

For those unsure what to believe, Elizondo offered these words of wisdom to a suspicious questioner at the 2018 International UFO Congress in Phoenix: "I would say remain skeptical. Healthy skepticism is very important; in fact, it's imperative. In fact, in my job as an intelligence officer, I was paid to be skeptical. I think you should always question all the information that comes before you by anybody who says anything, and I think that's true not just with people like me, I think it's true with government, religion, and everything in between." For a journalist trying to make sense of it all, the skepticism comes naturally. If Elizondo, Mellon, and the To The Stars Academy seem to be working in the great American tradition of P. T. Barnum, the irony remains that the Pentagon may well have its own good reason for keeping the UFO story alive. Not that they'd ever admit it.

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DIANE E. BAILEY AND INGRID ERICKSON

Selling AI: The Case of Fully Autonomous Vehicles

Advocates' claims about potential lives saved with self-driving vehicles are a misleading attempt to steer the discussion of traffic safety away from alternative approaches.

In the past several years, an array of technologists, economists, and technology pundits have predicted that advances in artificial intelligence (AI) are poised to revolutionize our lives, changing how we work, play, travel, shop, create, and more. The ensuing popular discourse often construes AI as the inevitable result of technological progress, against which we have no claim to stand. Promoters from multiple domains converge to inform us that AI is a socioeconomic boon, a superior alternative that can liberate human labor by replacing it with cheaper and more efficient computation. In other cases, promoters recast AI in more transformational terms as an innovative means to accomplish tasks beyond prior reach or as the only available or feasible solution for an intractable social problem. It is in this last instance that most promoters argue for the adoption of fully autonomous vehicles.

Specifically, the argument for the adoption of fully autonomous vehicles rests on a particular rhetorical strategy: that this AI-based technology constitutes the sole solution to the pressing social problem of motor vehicle deaths. AI, in this instance, not only provides the public with a ready solution to a recognized social problem, but comes to symbolize the recognized social good of safety. Unfortunately, promoters' persistent use of this rhetoric of safety has largely silenced the conception of, as well as the discussion of, alternative solutions to this problem. Moreover, it has focused our attention solely on motor vehicle deaths instead of encouraging broader conversations about the potential benefits of autonomous vehicles or considerations of helpful policies surrounding their deployment and use. Exploring this strategy raises fundamental questions about how society chooses to adopt and leverage AI technologies in the future.

The rhetoric of safety

In March 2017, a Tesla owner in California was killed in a crash while her car was in fully autonomous mode. In response, Tesla announced, "There are about 1.25 million automotive deaths worldwide. If the current safety level of a Tesla vehicle were to be applied, it would mean about 900,000 lives saved per year." In a similar vein, General Motors recently produced a 33-page report noting that 1.25 million people die globally each year in car crashes and asking us to imagine—as the company envisioned—a world with zero crashes. At the 2018 South by Southwest

Conference in Austin, Texas, John Krafcik, the chief executive at Waymo, Google's autonomous vehicle arm and the leader in this market, predicted that autonomous vehicles would reduce worldwide deaths by 1.25 million annually. In each instance, these automakers used the figure of 1.25 million to give weight to the claim that fully autonomous vehicles will have a huge, and therefore undeniably welcome, social impact. But this figure is an exaggeration.

From a technical standpoint, claiming that autonomous vehicles can save 1.25 million lives a year inflates the potential good of this technology because such a claim assumes that roads, driving conditions, and drivers in all countries match those in the key nations where the bulk of fully autonomous automotive technology is being developed (i.e., the United States, Germany, China, Sweden, the United Kingdom, South Korea, France, Italy, and Japan). Clearly, they do not. In the United States, fully autonomous vehicles are being designed to respond to visible road markers such as double yellow lines, curbs, and traffic lights, which means that they struggle in construction zones and other areas that lack the visible road markers that AI software applications such as lidar rely on for safe navigation. In India, where motor vehicle deaths rose between 1990 and 2015 to among the highest total in the world, many of the roads are in perpetual disrepair or under construction, few have road markers, and most are notoriously chaotic. Indian drivers are notably creative in navigating around these challenges, so much so that R. C. Bhargava, the chairman of Maruti Suzuki, the largest carmaker in India, was pessimistic about the potential of fully autonomous vehicles in his country. As he was quoted in *The Hindu*: "I think no technology will work here when nobody obeys any of the driving rules, nobody obeys any of the systems which are there." Similarly, past Uber CEO Travis Kalanick declared India as the last place one would want to develop fully autonomous vehicles.

Nor is India likely alone in having road conditions unfit for autonomous vehicles. In fact, India is not even among the top 25 countries in traffic deaths per capita. Using the figure of 1.25 million motor vehicle deaths per year to justify fully autonomous vehicles, therefore, is to argue that the technology can be applied in countries around the world without regard for local conditions. At best, this assumption appears unrealistic or naïve. It would not be a stretch to suggest that what works in the countries that are leading fully autonomous vehicle automotive technology are unlikely to work the world over.

Beyond the issue of exaggerated claims lies the equally important issue of the neglect of alternative solutions to the social problem of motor vehicle deaths, which promoters of autonomous vehicles argue should be solved with the replacement of human drivers. In the United States, per capita motor vehicle fatalities peaked in 1937, and total fatalities peaked in 1972. In other words, proponents of fully autonomous vehicles may be selling a solution to a problem that was already in steady decline due to alternative solutions well before the introduction of this technology. To determine if that is true, we must consider how, if at all, AI accounts for the decline of deaths in recent decades.

As many news outlets reported in 2015, technological improvements, including seat belts, airbags, anti-lock brakes, rear-view cameras, electronic stability systems, and improved structural systems, account for most of the decline in motor vehicle deaths since 1972. Some of the items on this list reflect electronic technology and automation in vehicles, including sensors and controllers, but none of them reflect AI. Moreover, technological improvements in vehicles are only part of the story of reducing motor vehicle deaths. Changes in traffic infrastructure, such as replacing stop signs and traffic signals with roundabouts and using video cameras for red light violations, have helped. Laws, regulations, and related policies also have played a role. For example, mandatory seat belt laws and penalties for distracted driving have been important factors, as has a cultural campaign against drunk driving, stricter laws, and sobriety checkpoints. Regulatory solutions such as lowering speed limits, enacting helmet laws, and putting in place graduated licensing for young drivers have also contributed. Going forward, this combination of vehicle technology, traffic infrastructure, regulation, and policy could achieve near-zero vehicle mortality rates without the introduction of any AI—another fact that highlights the weakness in the argument that fully autonomous vehicles are the sole solution for the social problem of motor vehicle deaths.

Evidence to support the claim that motor vehicle deaths can be reduced significantly without turning solely to fully autonomous vehicles appears in the 2018 report *The Road to Zero*, published jointly by the Rand Corporation and the National Safety Council. The report outlines how the United States could reduce motor vehicle deaths to zero by the year 2050. Although the report includes the introduction of fully autonomous vehicles as one of the steps toward achieving this goal, it acknowledges that full fleet penetration will take decades and presumes that humans will still be driving in 2050. This recognition is important, particularly given that developers of fully autonomous vehicles such as Tesla, Uber, and Daimler have recently ended some of their autonomous vehicle programs or pushed back their timelines for having vehicles on the road. How, then, does the report project zero motor vehicle deaths by 2050?

It does so primarily by advocating the adoption of the "Safe System" approach. This approach originated under different names in Sweden, the Netherlands, and Australia in the 1990s, and was first implemented in the United States in the early 2000s in the states of Idaho, Minnesota, and Washington. Whereas promoters of fully autonomous vehicles note that human error is responsible for most motor vehicle deaths and conclude that the answer is to replace human drivers with AI, the Safe System approach, while acknowledging that human error is inevitable, shifts attention away from human drivers toward good road design. In other words, it holds system designers, not individual drivers, responsible for motor vehicle accidents.

According to a 2018 joint report entitled *Sustainable & Safe*, published by the World Resources Institute (WRI) and the World Bank's Global Road Safety Facility, the Safe System approach succeeds by addressing factors such as "land use and mobility planning—to reduce vehicle dependence and promote safe, healthy, and environment-friendly travel modes; comprehensive speed management to set safe speeds; intersection design to allow people to cross safely; road design that accounts for human error; improved public transport; safe vehicle design and technology; and better coordination and quality of post-crash emergency response and care." For example, roundabouts prove a better design than traditional right-angle intersections because they slow traffic, eliminate crossing conflicts, and facilitate crash angles that result in less severe injuries. According to a 2004 study by Maryland's State Highway Administration, fatal accident rates decreased by 100% at intersections where roundabouts were installed in that state. Similarly, barriers at the side of roads (that prevent vehicles from running off the road into fixed obstacles such as trees and poles) and in the center of roads (that prevent vehicles from running into oncoming traffic) reduce the number of deadly head-on crashes.

Such strong results for Safe System implementations appear to be the norm, not the exception. Presenting the results of WRI's analysis of data from 1994 to 2015 across 53 countries, the *Sustainable & Safe* report revealed that those countries that had adopted a Safe System approach had both the lowest number of motor vehicle deaths per 100,000 inhabitants and the fastest rate of decline in those rates. In the United States, the three states that adopted a Safe System approach fared much better than those that did not. For example, Minnesota saw its motor vehicle deaths drop by 40% over a 10-year period. Similar improvements have been noted in New York City, which adopted the Safe System approach in 2013. Perhaps the most striking feature of the Safe System approach is its applicability in the low- and middle-income countries with high motor vehicle death rates and poor road conditions. The amenability of the Safe System approach stands in stark contrast to the problems that fully autonomous vehicles currently face in these countries.

The results of the Safe System approach as documented in the *Sustainable & Safe* report, in addition to the technical improvements in vehicle design and regulatory changes, call into question the rhetoric of safety proffered by the designers and producers of fully autonomous vehicles, such as the leaders of Tesla, GM, and Waymo who position fully autonomous vehicles as the main, if the not the sole, pathway to zero motor vehicle deaths. Automakers, however, are not alone in utilizing this rhetorical strategy. Investors, consultants, university professors, think-tank researchers, and even government officials have become perhaps the strongest voices advocating fully autonomous vehicles as a solution to motor vehicle deaths.

Not surprisingly, these additional promoters use many of the same tactics as the automakers in their rhetorical salvos. Adrienne LaFrance, writing for *The Atlantic* in 2015, noted, "Globally, there are about 1.2 million traffic fatalities annually, according to the World Health Organization. Which means driverless cars are poised to save 10 million lives per decade—and 50 million lives around the world in half a century." That quick calculation rests, again, on the faulty assumption that fully autonomous vehicles will work in all countries with equal efficacy. Investor Shahin Farshchi invoked a similar safety argument in his May 2018 *Forbes* article: "Studies show that many billions of miles need to be driven by autonomous vehicles until we can statistically prove that they are safer than humans. Unfortunately, thousands of lives will be lost at the hands of human drivers while we wait for those billions of miles to be driven autonomously."

The studies to which Farshchi referred were actually singular, not plural: a study conducted by two Rand Corporation researchers who developed quantitative models to calculate motor vehicle deaths for fully autonomous vehicles over many potential future conditions and policies. Rand's blog discussion of this study was picked up by news outlets across the country, many of which included a quote in the blog from Mark Rosekind, at the time head of the National Highway Traffic Safety Administration (NHTSA). Speaking at the Automated Vehicle Symposium in San Francisco in 2016, Rosekind said, "We can't stand idly by while we wait for the perfect. We lost 35,200 lives on our roads last year.… If we wait for perfect, we'll be waiting for a very, very long time. How many lives might we be losing if we wait?" The adoption of the safety argument was not a random speaking point by the head of this government agency at this symposium; on its website, NHTSA lists safety as the first benefit of fully autonomous vehicles. Of course,

contrary to what Rosekind implied, no one is standing idly by, most especially not the engineers and policymakers working on new non-AI solutions, including those in the Safe System approach.

Consulting firms such as McKinsey & Company, KPMG, J. D. Power and Associates, Boston Consulting Group, and Deloitte have also been strong advocates of the safety argument. In the course of helping their clients predict the market for fully autonomous vehicles, these firms have generated a slew of white papers, many of which prominently frame the safety benefits of fully autonomous vehicles. These papers are cited not only in countless media articles but also in the publications of university transportation research centers. For example, drawing on statistics from KPMG and McKinsey & Company, a 2017 publication from the University of Michigan's Center for Sustainable Systems stated that fully autonomous vehicles have the potential to reduce motor vehicle crashes by up to 90%, thereby saving lives.

Advanced by this diverse group of promoters, the safety argument undergirds appeals for the immediate development and testing of fully autonomous vehicles. The recent slight increase in US motor vehicle deaths between 2011 and 2016 has become a call to arms to address what promoters paint as an escalating problem. This rallying cry is perhaps most stridently, and somewhat ironically, made in the *Road to Zero* report, which argues that "The more than 37,000 people killed in crashes in 2016 represent a troubling reversal in previous progress. For the past several decades, all the important measures of roadway deaths—the total number, the number per population, the number per miles driven—were going down as a result of several factors, including changes in driving patterns, increased seat belt use, improvements in vehicle design, more-forgiving roadway designs, and stronger graduated driver's licensing programs for teen drivers. After reaching an all-time low in 2011, these trends began reversing in 2015, and got even worse in 2016."

The advocates make their case by a cleverly misleading presentation of the data. They choose the period 1985-2011 and characterize it as a time of steadily declining fatalities, and then describe 2011-2016 as a time of steadily increasing fatalities. The reality was not so neat. There were years of increase and decrease in both periods, and the increase during 2011-2016 is not proof of an emerging crisis. The recent rise in motor vehicle deaths may simply reflect the normal variation in these numbers as they have declined, steadily but unevenly, over time. In fact, the US Department of Transportation reports that motor vehicle deaths in 2017 declined 1.8% from their 2016 value, suggesting just the kind of variation that is obscured by the simplified data used by the advocates.

The trolley problem

One final aspect of the safety argument bears discussion. As early as 2015, writers of various hues, including technology pundits, ethicists, philosophers, scholars, and journalists, began to debate the "trolley problem" confronting fully autonomous vehicles. Originated in the 1970s as a moral dilemma, the trolley problem asks you to imagine an approaching trolley that is speeding toward a group of people (often 50, but sometimes as few as 5) who are tied to the rails and who will die upon impact. As an onlooker, you are offered the hypothetical chance to pull a lever that will divert the trolley to an alternative track to which (typically) a single person is tied. Will you pull the lever? Recast for the current situation, the trolley problem sparks discussions about how designers should design fully autonomous vehicles to handle the moral dilemmas the vehicles could face in the course of everyday operation. Literally hundreds if not thousands of articles online and in print have taken up the ethics of fully autonomous vehicles in the context of the trolley problem.

From the perspective of selling AI using the rhetoric of safety, what merits consideration about this interest in the trolley problem is that it presumes that deciding who an autonomous vehicle should strike and kill in a crisis driving situation is a central design question demanding immediate attention, and it takes for granted the very idea that AI should and will replace human drivers. Although many writers tackle the trolley problem with gravity, far fewer question why the promoters of fully autonomous vehicles are using a rhetorical strategy based on safety in the first place or, more broadly, how autonomous vehicles figure in the larger conversation surrounding the relationship between AI and humans.

Granted, the rhetoric of safety that promoters of fully autonomous vehicles use to sell AI to the public may be merely the latest attempt to link the promises of technology to pressing social problems, little different from such attempts for a long line of technological advances put forward in the past. But to dismiss this current strategy as little more than run-of-the-mill techno-optimist hype would be to ignore the problematic fact that this narrow focus on motor vehicle deaths limits and obscures a broader discussion, both nationally and internationally, that ought to be had about the wide array of possible individual and social effects that futurists predict will be ushered in with the adoption of fully autonomous vehicles.

For example, at the individual level fully autonomous vehicles may ease the transportation burdens that individuals with physical or cognitive disabilities face, helping them not to miss medical appointments (a change that could save the health care industry billions of dollars) and making it possible for them to work outside the home. Similarly, autonomous vehicles may prove advantageous

for the elderly, whose own mobility may have suffered when they gave up or curtailed their own driving. Working mothers stretched for time might find compelling the idea of autonomous vehicles that chauffeur their children to after-school activities. Although these and many other imagined individual uses portend positive outcomes, a recent review of academic studies of autonomous vehicles published by London's Department of Transport warns that limited research has been undertaken to study the willingness, desire, and ability of the disabled, the elderly, or parents to employ autonomous vehicles. Moreover, not all individual use cases may be positive. For example, scholars contemplating the impact of autonomous vehicles on urban tourism have entertained the possibility that prostitution and drug use might shift from "hotels-by-the-hour" and street corners to roaming autonomous vehicles.

Individual use, illicit and otherwise, of autonomous vehicles may increase motor vehicle trips as people consider taking trips that they otherwise would have avoided (perhaps because they no longer lose time spent driving), thus causing concerns for rising greenhouse gas emissions that would constitute a negative societal outcome. Many other societal outcomes surface when futurists consider a switch from the model of individual vehicle ownership that exists today to a fleet-based scenario in which autonomous vehicles operate as a shared service. These outcomes include fewer vehicles in service, decreased traffic congestion, reversed urban sprawl, less urban space devoted to parking, lower insurance costs, fewer and less expensive vehicle repairs, reduced oil dependency, increased economic development, improved access to retail and jobs, and higher worker productivity. As at the individual level, however, not all envisioned societal outcomes are positive. Among potential negative outcomes are downward pressure on the earnings of commercial truck drivers, reduced revenue for small cities that rely on payments from traffic violations, fewer symbols for human navigation (i.e., road signs), and concentrated power in the hands of autonomous vehicle fleet owners.

In short, fully autonomous vehicles have a range of favorable and unfavorable potential outcomes for individuals and society, some of which futurists have begun to envision and others of which they have not. Moreover, these outcomes will affect a wide variety of constituent actors (e.g., riders, drivers, people in a range of occupations and professions, cities, and infrastructures) in direct as well as indirect ways. As a public, we should be keen to understand the complexities of autonomous vehicle adoption and use, and be eager for the opportunity to discuss these complexities imaginatively and responsibly. Further, we need to investigate, on the basis of such a discussion, the types of public policy that would best support the adoption and use of autonomous vehicles.

Wittingly or unwittingly, however, promoters of fully autonomous vehicles stymy this important discussion and investigation by inveigling us rhetorically into thinking that the realities we will soon encounter can best be understood and contained within the narrow focus of an AI-enabled solution to motor vehicle deaths.

We do not contest the inherent or potential safety of fully autonomous vehicles, despite recent accounts of deaths during testing or use of them on public roads. Rather, we challenge the rhetorical strategy of "selling" this particular AI-based technology using a safety argument. This argument is riddled with problems of logic that become more than evident when weighed against the relevant facts. As citizens, policy-makers, and lawmakers we should demand better before it is too late. Specifically, we should demand a broader discussion about autonomous vehicles that includes consideration of the full array of possible use scenarios, outcomes, and relevant and necessary policies.

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Recommended reading

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Pending Memories: Adrian Fernandez

The latest series of photographs by Cuban artist Adrian Fernandez portray the backside of billboards situated in surreal landscapes. The complex structures and unexpected shapes are suggestive of Russian constructionism, but the more interesting question is what is on the other side.

Pending Memories is partially inspired by changes to Cuba's visual culture since its revolution in the 1950s. The photographs hint at the propaganda billboards, banners, and industrial sites erupting throughout the traditional landscapes of cities and countryside. Inspiration for this series began when Fernandez visited Las Parrandas de Remedios, the annual Christmas festival in Remedios, Cuba. One of the major attractions at the festival is a cathedral-like façade built solely for the support of lights and images that are a rallying point for the festival participants. According to the artist, "Being inspired by such an event, I initially intended to document these massive structures but only being photographed from the rear angle, never the front. The problem with such a procedure is that this festivity happens only once a year, giving me very little room to work. This situation led me to start considering creating my own structures, based on drawing and designs previously conceived and then placed in any context or space I saw fit."

The initial challenge for this project was to find a team of collaborators who would help translate ideas of the imagination into photographic images. The consulting team consisted of an engineer, an architect, and a designer who worked with Fernandez to create structures that are as fantastical as an M. C. Escher drawing, yet are realistic and believable.

In the collaborative process, the engineer and architect work together to design and build the relatively small structures. Fernandez then chooses and photographs a landscape into which the structure will be virtually introduced. The designer then stages the structure with lighting and background that match the environment of the landscape photo. The separate photos of the structure and the landscape are then merged into a single image. Fernandez oversees the entire process, including the final printing process.

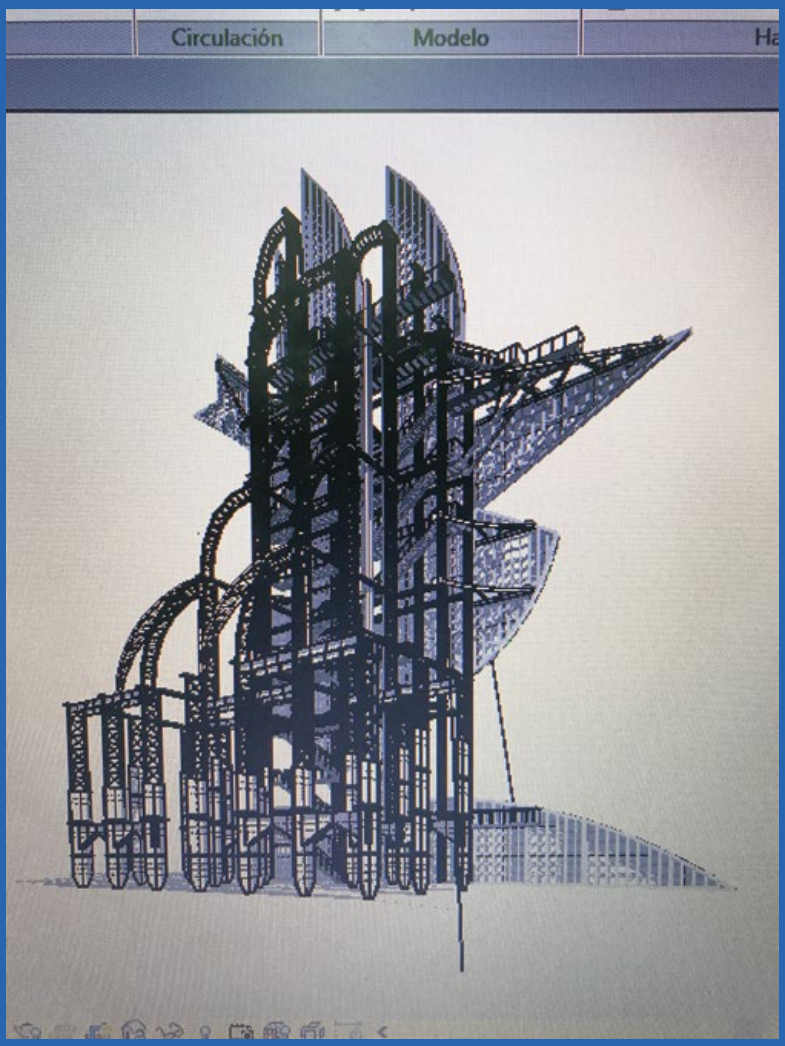
To learn more about photographer Adrian Fernandez, visit: adrianfernandezphotography.com.
All images are courtesy of the artist. © Adrian Fernandez 2019.

ADRIAN FERNANDEZ
From *Pending Memories* series,
Untitled No. 10, 2018-19

ADRIAN FERNANDEZ
From *Pending Memories* series,
Untitled No. 15, 2018-19

ADRIAN FERNANDEZ
From *Pending Memories* series,
Untitled No. 17, 2018-19

ADRIAN FERNANDEZ
From *Pending Memories* series,
Untitled No. 5, 2018-19



ADRIAN FERNANDEZ
Above and left: Computer rendering for the series *Pending Memories*, 2018-19

ADRIAN FERNANDEZ
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Who Will Set the Rules for Smart Factories?

Leadership in information governance will provide a first-mover advantage to the nation's manufacturing sector.

Globalization and advanced technology have defined twenty-first century manufacturing, creating a hypercompetitive environment where continuous growth in productivity has become imperative—not just for the success of firms, but for their survival. Nowhere is this more apparent than in the movement toward smart manufacturing—defined by the National Science and Technology Council as "the integration of sensors, controls, and software platforms to optimize performance at the production unit, plant, and supply chain levels." Such digital integration, facilitated by what is being called the Industrial Internet of Things, allows for real-time decision-making via data analytics, including the use of artificial intelligence (AI) techniques, such as machine learning.

A chorus of voices—from consulting firms, market research firms, manufacturers, and government agencies—believe that owners of smart factories will reap huge economic rewards from enhanced sensing and monitoring, seamless data transmission, new waves of automation, and analysis of big data. Some market forecasts suggest that these factors can produce $1 trillion in added value by 2025—which could translate into a doubling of operating profit for a typical manufacturing firm. In the minds of many, digitalization represents the next industrial revolution.

Getting there, however, won't be easy. It will require massive investment in capital equipment, labor (new skills will be needed), and technology (R&D). And it will be shaped by information governance—norms of behavior for the creation, transmission, storage, analysis, use, valuation, security, and deletion of information. These norms of behavior—or rules—are still evolving. Drawn by the high stakes, leading manufacturing nations have come to the table to set the rules. Whichever nation prevails will provide its domestic producers with a competitive edge.

Elements of information governance

Before exploring what nations are doing, let's first describe the key elements of information governance. They include, but are not limited to, technical standards, cybersecurity, data privacy, digital trade, and AI.

Technical standards are specifications, in the form of rules or guidelines, for materials, products, processes, or services (such as communication between machines, systems, hardware, and software). Standards often are based on technologies that embody intellectual property (IP). Without technical standards to govern the flow of information within and across a firm and its supply chain, smart manufacturing cannot happen.

Smart manufacturing will rely on highly integrated value chains, which will raise the stakes for cybersecurity. Value chains comprise the full range of activities that businesses go through to bring a product or service to their customers. The integration of information technology (IT) and operations technology (OT)—a necessity for the creation of smart factories—raises particular challenges. Most existing OT systems do not have the capacity to add cybersecurity protections without an adverse impact on production.

Smart manufacturing will involve the collection and management of personal information (on workers, customers, and suppliers), which is increasingly subject to local, state, federal, and international regulation. Data will become increasingly valuable as inputs and assets for manufacturing firms, which will reshape relationships between firms, workers, customers, and suppliers. This will require an emphasis on privacy. For example, the European Union's (EU) General Data Protection Regulation (GDPR), which went into force on May 25, 2018, is having an impact well beyond that of its member states, and is inducing changes

in the practices of global manufacturers.

Digital trade is a broad concept, capturing data flows across global value chains, services that enable smart manufacturing, and other platforms and applications. As nations create policies to benefit their domestic industries, international disputes over digital trade will become more frequent and consequential. Provisions governing digital trade can be seen in new trade agreements, such as the Comprehensive and Progressive Trans-Pacific Partnership, a free trade agreement between 11 countries in the Asia-Pacific region.

The application of AI—using algorithms that find patterns in data and facilitating decisions based on those patterns—in a manufacturing setting is growing. AI is being used to design new products, train workers, create collaborative robots (cobots), enhance quality control, and optimize supply chains. Future applications may require modernization of outdated regulations and/or the development of new rules to address issues unique to AI-enabled goods such as autonomous vehicles, medical devices, and aerospace components. Norms for the application of AI (via regulation or standards or other means) will therefore impact smart manufacturing.

It is not difficult to foresee these elements of information governance shaping and limiting opportunities for smart manufacturing. Interoperability—which cannot be achieved without technical standards—is critical to the advent of the Industrial Internet of Things. Lax cybersecurity somewhere along a complex and multifaceted supply chain will create a vulnerability for manufacturers and therefore discourage investment in supply chain integration. Policies that limit the flow of digital information across national borders (e.g., data localization requirements) can and will become nontariff trade barriers.

Different nations, different approaches

Economists have long observed that developing countries utilize industrialization as a tool for productivity and growth. Even wealthy nations seek to foster domestic manufacturing—by offering incentives for the production of goods with ever greater added value. Increasingly, they do this through public policies that promote innovation. A recent report from the Information Technology and Innovation Foundation documented 10 countries with national plans to digitalize their manufacturing sectors. Together, these countries dominate global manufacturing today—and they aim to maintain or elevate their relative position through smart manufacturing.

A close look at three leading manufacturing nations reveals very different approaches toward smart manufacturing and information governance. We label these approaches as managed (China), coordinated (Germany), and market-driven (United States) to reflect the government's role toward its manufacturing sector. Table 1 summarizes the major differences in approach between these countries.

China's managed approach. In 2011, China surpassed the United States to become the leading manufacturing country in terms of total value added (i.e., total sales less the total cost of purchased inputs, such as raw materials and electricity), but is just tenth in value added per capita because of its huge population. In terms of spending on manufacturing R&D, China leads the world. See Table 2.

China's rise as a manufacturing country coincided with its admission to the World Trade Organization in 2001. However, China has come to recognize that the strategy that led to its success is neither sustainable nor desirable. It sees the threat posed by lower-cost production in developing countries (over the past decade, China's labor costs have risen 10% per year, a consequence of its remarkable rise in labor productivity).

For China, it is imperative that its economy avoid the so-called middle income trap: when growth slows after a country reaches middle-income status. With smart manufacturing, China aims to lead in the production of the highest-value-added products, and it aims to get there quickly. As China's president, Xi Jinping, recently noted, "The Fourth Industrial Revolution is unfolding at an exponential rather than a linear pace."

China's approach to smart manufacturing and its information governance can be characterized by several basic factors: a top-down approach in which government sets long-term performance goals and intervenes as necessary to achieve these goals; policies and practices that ensure Chinese firms become global leaders; and placement of individual rights as subservient to national goals. This approach can be seen most clearly in China's long-term manufacturing plan, in its development of technical standards, in its new cybersecurity law, and in its approach to AI.

Made in China 2025. In 2015, China announced its Made in China 2025 (MIC2025) strategic plan. Inspired by Germany's Industrie 4.0 strategic initiative, the plan is both broad in coverage (much of its content would benefit all of manufacturing) and narrowly targeted (covering 10 specific subsectors). It is supplemented by dozens of other policy documents, some of which are complementary (e.g., the Internet Plus Action Plan and the MIC2025 Major Technical Road Map) and others that are subsidiary (e.g., more than 70 provincial plans issued to align with MIC2025). MIC2025 is heavily supported with public funding—to a much greater extent than in either Germany or the United States.

Technical standards. China recognizes the strategic importance of global technical standards—and the IP embedded in such standards. In the beginning of this century, its manufacturing sector utilized standards based on intellectual property owned by foreign firms. This led the country to seek low royalty payments in exchange for market access. Over time, as its economy grew and its manufacturing firms became more sophisticated, China shifted its strategy. Its government participates actively in global standard-setting bodies that are of strategic importance. And it is aggressively writing standards for emerging technologies to benefit its own firms. It reportedly

Table 1. **Three Approaches to Smart Manufacturing**

Country	Motivation	Approach	Characteristics	Examples	Major Disadvantage
United States	Address erosion of the "Industrial Commons"	Market-driven	preference for private-sector leadership reluctance to impose mandates	Manufacturing USA cybersecurity framework revised NAFTA	ceding global policy leadership to other countries
Germany	Maintain historically strong global leadership position	Coordinated	active role for government significant input from all stakeholders	Industrie 4.0 General Data Protection Regulation Network Information Security Directive	its high-tech sector can't compete with US and China
China	Avoid falling into the middle-income trap	Managed	top-down performance goals policies and practices to advantage Chinese firms individual rights subservient to national goals	Made in China 2025 cybersecurity law AI plan	dependent on foreign technology and investment

is "exporting" its own standards through its "Belt and Road" initiative.

Cybersecurity. China's cybersecurity law, which went into effect in June 2017, is premised on cyberspace sovereignty—something China has long asserted with respect to the internet—and has been described as emphasizing security over the free flow of data and freedom of speech. Provisions of the law apply to "network operators," defined as all businesses that manage their own data network (including email), and to "critical sectors," which include energy, transport, water, financial services, and public services. It requires covered entities to store select data within China (data localization), prohibits information and data on Chinese citizens to be sent abroad without government permission, and allows Chinese authorities to conduct spot checks on a firm's network operations (which could include providing source code). China has also issued data protection standards, modeled after the EU's GDPR, that detail how individual consent can be obtained from Chinese citizens.

AI. China not only plans to lead the world in AI technology (by 2030), but also in AI governance through development of standards, including standards on ethical and social issues related to AI. In 2018, China created an AI road map that lists 23 critical near-term standards and 200 other standards that have been issued or are under development. The Chinese government plays an active role in writing AI standards.

China's road to smart manufacturing faces a major hurdle: it will be very expensive, much more so than for Germany or the United States. There are several reasons. China has a larger manufacturing sector than Germany or the United States, so it will simply take more resources to transform it. A significant proportion of Chinese manufacturing is technologically deficient, so China has much farther to go to create smart factories than its major strategic competitors. Its managed approach necessarily has a higher failure rate (a higher percentage of bad investment decisions) than would a nation with a true market economy. And China must also change its product mix to suit foreign tastes: making three-wheeled minicars for its domestic market is not the same as making luxury and performance vehicles for export to the EU or the United States.

Can China achieve its long-term goals without leveraging significant foreign investment and foreign technology? Probably not. Can it continue to attract foreign capital absent reforms that accelerate the country's transition to a true market economy? If not, then China faces a catch-22 of sorts: to

Table 2. **Leading Manufacturing Nations by World Rank**

Country	Value Added in Manufacturing	Value Added in Manufacturing per Capita	Manufacturing R&D Spending
United States	2	4	2
Germany	4	1	4
China	1	10	1

Sources: World Bank and Congressional Research Service.

achieve world-class leadership in smart manufacturing, it must reform the very approach that it is counting on to get it there.

Germany's coordinated approach. Germany has long been a global leader in manufacturing. It is the world leader in value added per capita. It is fourth in manufacturing R&D spending. The share of its economy devoted to manufacturing is among the highest in the world and has remained remarkably stable over decades while those of other industrialized nations have waned. Its trade balance in manufactured goods is large and positive, making it an export-driven sector. The high quality of its products—consider machine tools—is both globally admired and the envy of its strategic competitors.

Key drivers of Germany's success in manufacturing include a highly skill-intensive labor force; a rich network of policies and institutions (e.g., the research-oriented Fraunhofer institutes located throughout the country) that enable German companies to maintain high productivity; a high degree of entrepreneurship (embodied in its small- and medium-sized enterprises, collectively known as the Mittelstand, that form the backbone the country's economy); and its strategic management of place, or Standortpolitik, in which each state, region, and city has a mandate with the responsibility to achieve and sustain economic prosperity. In Germany, it is up to the local community, working closely with the state and federal levels, to not only leverage and build on its strengths but also implement many of the key policies, such as the apprentice system, technical universities, translational knowledge institutions, and support of the Mittelstand.

All of these factors are reflected in Germany's approach to smart manufacturing. Launched officially in 2013, Industrie 4.0 (inspired by the fourth industrial revolution) is designed to maintain the country's position as a global leader in manufacturing through digitalization. The initiative is led by the German government, but includes manufacturing firms, trade associations, research institutions, labor organizations, and academia. One recent study reported 159 diverse organizations working in close collaboration with leading businesses.

Information governance to support smart manufacturing in Germany (and the EU) is characterized by an active role for government as coordinator, with significant input from citizens and the private sectors. This coordinated approach can be seen with respect to the country's approach to technical standards, privacy and digital trade, and cybersecurity. Indeed, Germany can be considered the global leader in information governance for smart manufacturing.

Technical standards. Germany is ahead in the development of technical standards for smart manufacturing. Its Industrie 4.0 initiative supported development of the Reference Architectural Model for Industrie 4.0 (RAMI), which is a guide to standards and interoperability. Germany is aggressively pushing development of its standards, which are widely considered rigorous and comprehensive.

Privacy and digital trade. German Chancellor Angela Merkel said the EU needs to find its place between the United States, where personal data is easily privatized, and China, where, in her words, "the state has mounted a takeover." Germany was the first EU country to adopt the General Data Protection Regulation, which went into force in May 2018. Under GDPR, EU citizens control how their personal data can be collected, used, and stored. Firms outside the EU face a choice: align with GDPR (under penalty of hefty fines) or be shut out of the EU market. Through GDPR, the EU is influencing cross-border data flows.

Cybersecurity. Germany is well known to have a disproportionate influence on the 28-member European Union, and this influence is evident on cybersecurity. The EU Network Information Security (NIS) Directive, recently enacted, is largely based on Germany's own 2015 cybersecurity law.

Like GDPR, the NIS Directive, which went into effect in May 2018, is influencing the behavior of firms outside the EU. Global firms prefer to follow one standard of practice. Because the Directive is the first to define "minimum standards of due care" for critical infrastructure protection, firms that comply may obtain some legal protection from lawsuits alleging mishandling of personal information.

The German approach to smart manufacturing, however, does have its Achilles' heel: its high-tech sector cannot compete with global leaders such as the United States. To some observers, Germany intends to compete by creating the rules that other countries must follow. Regarding AI, the emerging EU approach has been defined as "ethical AI," to differentiate it from leading efforts elsewhere (e.g., China and the United States). Germany's AI strategy will feed into the EU plan, which aims to secure a global foothold by positioning it somewhere between the contrasting US and Chinese approaches. The United States and China, however, enjoy advantages of scale, which is a huge advantage in AI (but perhaps less so in a well-controlled, relatively predictable manufacturing environment). Can Germany (and the EU) carve a leadership role in AI through governance, as it has with privacy and cybersecurity?

United States' market-driven approach. The United States is the world's second-leading country in terms of manufacturing value added and fourth in terms of value added per capita. It is second in terms of manufacturing R&D spending.

US global leadership in manufacturing, which emerged in the decades following World War II, is a subject of much debate. Although the manufacturing share of real gross domestic product (GDP) has remained relatively constant for decades—a good thing—productivity growth since 2004 has been sluggish or even negative in many subsectors—a source of worry.

The US approach to smart manufacturing can be characterized by a preference against government mandates and a reliance on markets and private-sector leadership. Compared with Germany and China, this approach has the advantage of not committing too early to a particular legal prescription that may fail in the marketplace. The US approach is most evident in its

Manufacturing USA program, standards development, the creation of voluntary frameworks for cybersecurity and privacy, digital trade, and posture on AI.

Manufacturing USA. Congress enacted legislation in 2014 to address concerns about the decline in US manufacturing competitiveness (exemplified by a sharp drop in manufacturing employment in the first decade of this century and by sluggish productivity growth since 2004). The Reinventing American Manufacturing and Innovation (RAMI) Act ratified the creation of Manufacturing USA, a federal program to support collaborations between government, industry, and academia through new institutes that would center on particular advanced technologies. The aim was to bridge the so-called valley of death in precompetitive manufacturing technologies and allow domestic manufacturers to more fully reap the rewards from government-funded R&D.

Inspired by Germany's famed Fraunhofer Institutes, the US program currently comprises 14 institutes that are geographically dispersed. Each institute has a federal agency sponsor and is managed by a third party, often a nonprofit entity set up through a university. Each institute focuses on a particular set of related technologies. Smart manufacturing is the focus of the Digital Manufacturing and Design Innovation Institute (DMDII), based in Chicago, which is sponsored by the Department of Defense (DoD), and the Clean Energy Smart Manufacturing Innovation Institute (CESMII), based in Las Angeles, which is sponsored by the Department of Energy. Federal funds are approved for a five-year period for each institute. The federal funding level is typically $70 million to $110 million per institute, matched or exceeded by funding from private industry and other nonfederal sources, with a minimum 1:1 cost share. To date, the federal-nonfederal ratio exceeds 1:2.

Technical standards. The United States does not have a formal national strategy with regard to smart manufacturing standards other than to facilitate innovation and allow the best solution to emerge. But there are active initiatives from multiple groups and organizations, including government organizations, such as the National Institute of Standards and Technology (NIST); organizations focused on standards development, such as Underwriters Laboratories; research institutes, such as DMDII and CESMII within Manufacturing USA; and individual companies. In general, the United States encourages a voluntary, consensus-based approach where government agencies participate when invited by industry. The lack of a single driving national strategy does not provide the same level of certainty for investment as compared with the standard-setting approach of China or even Germany.

Cybersecurity and privacy. Currently, the United States does not impose requirements for cybersecurity on US manufacturers. Firms wishing to conduct due diligence with respect to cybersecurity can look to NIST's Cybersecurity Framework, guidance from the Federal Trade Commission (FTC), and the DoD's Deliver Uncompromised initiative.

The NIST framework was born out of private-sector resistance to a mandatory approach imposed either by legislation or regulation. The Obama administration empowered NIST to partner with industry and develop a voluntary, risk-based framework that would be based on industry best practices and that could be applied to firms of all types (not just manufacturing). First developed in 2014 and most recently revised in April 2018, it sets a floor for cybersecurity.

The FTC has the authority to create rules to block "unfair or deceptive acts or practices" by companies doing business in the United States. Thus far, the commission has acted only in reaction to bad practices: it has levied penalties against companies whose cybersecurity practices do not match their advertising or those that operate in critical infrastructure sectors.

The US approach to smart manufacturing can be characterized by a preference against government mandates and a reliance on markets and private-sector leadership.

Spurred by reports of serious vulnerabilities in its supply chain, especially by small firms, the DoD is taking steps to raise cyber standards by requiring its top-tier contractors to ensure that lower-tier suppliers are adhering to best practices. Its most recent effort, the Deliver Uncompromised initiative, aims to build on the three pillars of sourcing (price, delivery, performance) by adding a fourth pillar, security.

On privacy, NIST has begun development of a voluntary framework for privacy protection, modeled after its risk-based cybersecurity framework. It is unclear how influential this framework may be, given the first-mover advantage enjoyed by the EU with its mandatory GDPR.

Digital trade. President Trump has pushed for better trade deals to enhance US manufacturing, arguing that "careless and unfair trade deals" are partly at fault "for the diminished state of American manufacturing today." He continued: "These deals have severely disadvantaged American exports. My Administration, however, will right these wrongs and ensure a level playing field for American manufacturing going forward.... American drive, ingenuity, and innovation will ultimately win."

Perhaps the clearest indication of this sentiment can be found in the Trump administration's effort to replace the North American Free Trade Agreement (NAFTA). The proposed (though not yet officially adopted) version is called the

United States, Mexico, and Canada Agreement (USMCA). USMCA reflects not only the US approach to smart manufacturing but opposition to the approach of China. The agreement includes a commitment by all parties to ensuring the free flow of information, making large government data sets publicly available (which will advance AI), protecting source code and algorithms, and striving for consensus-based technical standards. It also includes provisions to address mechanisms used by China to foster its domestic manufacturing sector, including the use of state-owned enterprises (emphasizing transparency), currency manipulation (prohibited), data localization requirements (prohibited), and trade agreements with nonmarket economies (consultation with the other USMCA signatories is first required).

AI. The Trump administration is making US leadership in AI a priority. The president created a select committee on AI under the National Science and Technology Council, and he convened a White House summit in the spring of 2018 to highlight the administration's actions. These actions include prioritizing funding for R&D, removing regulatory barriers to innovation, training the future US workforce, achieving strategic military advantage, leveraging AI for government service, and leading international AI negotiations. Most recently, the president issued an executive order to ensure interagency coordination on AI, including a NIST plan for AI standards development and an Office of Management and Budget plan for regulation.

The US market-driven approach can be seen as promoting innovation, but it has also drawn fire. Critics contend that the United States is ceding leadership in information governance to other countries or regions of the world. Their argument is that global firms, which adhere to a common standard to guide their far-flung operations, are heavily influenced by the most stringent requirements in those nations in which they operate or wish to operate. Experienced policy-makers and advocates know that "policy abhors a vacuum" and that "you can't fight something with nothing." To some, the United States—with its "hands off" approach—runs the risk of losing in the race to establish rules for information governance. And losing would carry a heavy weight. Leadership in information governance will provide a first-mover advantage to a nation's manufacturing sector. Firms that have the most experience operating under a set of norms have a competitive advantage over competitors subject to a steep learning curve.

Lack of federal leadership on information governance is already causing problems domestically. Federal inaction has led individual states to impose their own rules (e.g., California has developed its own regulations to protect personal privacy), creating a patchwork of state laws that create friction for interstate commerce.

Policies for improvement

Before we offer policy recommendations, we make an important presumption. The approach that a nation takes to foster domestic manufacturing—managed, coordinated, or market-driven—will not change. The choice of approach reflects a mix of cultural, social, and political forces over time. It is shaped and informed by national systems of innovation, and these systems tend to change slowly.

Within its chosen approach, however, a nation can and will change its strategy—to respond to the actions of its competitors (Made in China 2025 was influenced by Industrie 4.0 and Manufacturing USA); to political pressures (the election of President Trump elevated in priority US scrutiny of China's trade policies); and to its own evolving capabilities in manufacturing (elements of Germany's Industrie 4.0 are first being applied to its favored and world-class automotive and machine tool industries).

The lack of a single driving national strategy in the United States does not provide the same level of certainty for investment as compared with the standard-setting approach of China or even Germany.

How should the United States alter its strategy toward information governance to best ensure leadership in smart manufacturing? We offer three sets of recommendations: current initiatives that demonstrate US leadership should continue, the federal government should better leverage its power as a purchaser of manufactured goods, and the National Research Council (NRC) should convene a committee to develop policy recommendations.

The current initiatives that should be continued are:

- Congress should reauthorize Manufacturing USA (otherwise its federal funding might cease). The institutes created under this umbrella program to focus on smart manufacturing are working on the cutting edge of technology development and are almost certain to yield major advances. And aside from their technological roles, the institutes engage in important and pressing information governance issues, such as standardization.
- Congress should enact the proposed USMCA so that the United States can engage and shape the global landscape on information governance and digital trade.
- The Office of the United States Trade Representative (USTR), which oversees trade negotiations with other countries, should continue to bring cases to the World

Trade Organization when other nations create rules for information governance that act as nontariff trade barriers (e.g., data localization requirements).
- NIST should continue developing a risk-based approach to privacy, which will represent an alternative to (and perhaps an improvement over) GDPR.

The federal government should leverage its power as a customer to propagate norms of behavior for business. Specifically, DoD should leverage its supply chain to advance smart manufacturing. A significant share of domestic manufacturing is defense-related. Historically, DoD has played a big role in the development of technologies and products that have advanced the US economy and benefitted US firms. DoD can and should use its leverage to make the defense supply chain a leader in smart manufacturing, starting with cybersecurity.

The NRC should convene a committee to develop policy recommendations to advance smart manufacturing in the United States. As part of its review, the council should take a hard look at the strategic actions of other nations, especially China and Germany; the degree of coordination among federal government agencies; and governmental options to accelerate private-sector investment. Each is critical.

The actions of China and Germany are purposeful—to create information governance that will drive smart manufacturing and benefit their domestic industries. The actions of the United States, in contrast, represent a laissez faire mindset that, to some observers, seems complacent given the progress being made by its strategic competitors. An NRC review should consider the pros and cons of alternative strategies that the United States could employ.

Some aspects of information governance have received significant attention from federal agencies (e.g., USTR on digital trade). However, given the number of federal agencies with a stake in smart manufacturing, more holistic attention is called for. For example, the US plan for leadership in advanced manufacturing, released in October 2018, mentions smart manufacturing but emphasizes technological innovation and fails to acknowledge the role of information governance. President Trump's manufacturing council, which might have played an important role, was disbanded—for political reasons—soon after it was established. The NRC should recommend specific steps to improve interagency coordination and US leadership.

In her 2014 book, *The Entrepreneurial State*, Mariana Mazzucato documented many successful examples where the government reduced financial risk for the private sector, including in the development of technologies such as the smartphone and breakthrough drugs. The government—as reducer of risk and purveyor of certainty—thus plays a huge role in facilitating and shaping innovation. The NRC should consider this and the full range of options that the government might employ to facilitate private-sector investment in smart manufacturing.

The need for collective action is clear and growing. As technological capabilities expand, progress in smart manufacturing will increasingly be shaped by information governance. And just as firms prefer to operate where tax and regulatory policies improve their bottom line, firms are likely to preferentially invest where information governance is most favorable. As a consequence of these investment decisions by individual firms, global value chains—and the economic power they wield—will shift. The nation that leads in information governance will give its domestic producers a competitive edge.

Of the different approaches to smart manufacturing being taken by the United States, China, and Germany, it is not yet clear which will prove most fruitful. Thus, the United States must not paint itself into the proverbial corner. Future US actions should be informed by the strategic behavior of other nations, the degree of coordination among federal government agencies, and the best use of governmental resources to accelerate private-sector investment.

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Parsing the Waters

The Trump administration's efforts to reform US wetlands policy are a century or more out of date. All the same, wetlands protection would benefit from a clearer policy foundation.

In June 2018, President Trump issued an executive order, "Restoring the Rule of Law, Federalism, and Economic Growth by Reviewing the 'Waters of the United States' Rule," that directed the Environmental Protection Agency (EPA) and the US Army Corps of Engineers to review and rescind an Obama-era rule defining "navigable waters" under the Clean Water Act. Acting on this executive order, EPA and the Corps have proposed a new definition of "Waters of the United States" (WOTUS) that would include traditional navigable waters, tributaries to these waters, certain lakes and ponds, and wetlands immediately adjacent to jurisdictional waters.

This definition constitutes a significant reduction in scope of the government's regulatory domain, which has also included intermittent streams, prairie potholes, wet meadows, mudflats, sandflats, sloughs, playa lakes, and other wetland features. The proposed WOTUS Rule also marks a reversal of a century of effort to bring science's evolving understanding of wetlands into line with government's authority for protecting and improving the nation's environmental quality. Not surprisingly, then, the rule has been met by resistance on the part of environmental advocacy groups and members of the wetland and conservation science communities. But the significance and impact of the rule change can be understood only in the broader context of how US wetland policy has evolved along with shifts in cultural outlook, economic imperatives and opportunities, and relevant scientific and technological developments over the course of the nation's history. This historical perspective points toward both the abiding importance of wetlands for the nation and the need for a policy framework that can assure stewardship of wetlands even in the face of changing political winds.

The age of reclamation

At the time of European settlement, the area that would later be known as the continental United States contained roughly 221 million acres of swamps, marshes, mires, and bogs. For a long time, these features were regarded as something to be avoided, as sources of "ill ayers," pestilence, and "covert" for savages and "loos and evil persons." During the early years of the fledgling republic, the term "swamp" did not serve as an ecological category so much as a pejorative denotation for lands unfit for agriculture or other types of development. Prompted in part by miasma theory and other now-dismissed disease etiology, early policies focused almost exclusively on the eradication of swamplands, a process that came to be called "reclamation."

These policies predate the founding of the United States. Colonial authorities made legislative efforts to modify the environment and eliminate negative effects of the original landscape as early as 1685. As arable land along the coast became scarce, the draining of bogs and marshes became a common solution, with some projects covering thousands of acres. Well before the American Revolution, colonial assemblies in Massachusetts, Connecticut, South Carolina, and New York authorized and funded projects to drain marshland to support tillage and pasturage. In 1764, Virginia chartered a private corporation to drain the Great Dismal Swamp.

The foundation for regulation of wetlands in the United States is derived through Article 1, Section 8—the Commerce Clause—of the US Constitution, which established the basis for federal authority over navigable waters and gave rise to the concept of "Waters of the United States." After the ratification of the Constitution, however, state governments continued

colonial reclamation policies with little to no modification. During the first half of the nineteenth century, federal government attention focused on westward expansion and settlement, including enactment of numerous land disposal acts and subsidy programs that tended to expose wetland habitats to developmental stress. In particular, construction of the transcontinental railroad required extensive wetland reclamation for right-of-way clearing, as well as consumption of wetland forest products needed for ties, bridges, and fuel. Between 1849 and 1880, Congress passed three Swamp Lands Acts ceding wetland areas "unfit for cultivation" to the states. Because the laws did not carefully define "uncultivability," they were subject to frequent and opportunistic abuse. Speculators used the laws to privatize almost 65 million acres, much of which was more valuable than had been envisioned under the original swamp land acts. The Reclamation Act of 1902 established the US Reclamation Service to further enable westward expansion and settlement through irrigation projects, water transfer and storage infrastructure, and reclamation of land not easily cultivated. Now known as the Bureau of Reclamation, its "subjugation" of land for human use undoubtedly contributed to the loss of US wetlands.

Prompted in part by miasma theory and other now-dismissed disease etiology, early policies focused almost exclusively on the eradication of swamplands, a process that came to be called "reclamation."

During this era, reclamation activities were enabled by scientific and technological advances such as the invention of blasting caps and nitroglycerine, steam- and oil-powered dredging units, and mass production of drainage tiles.

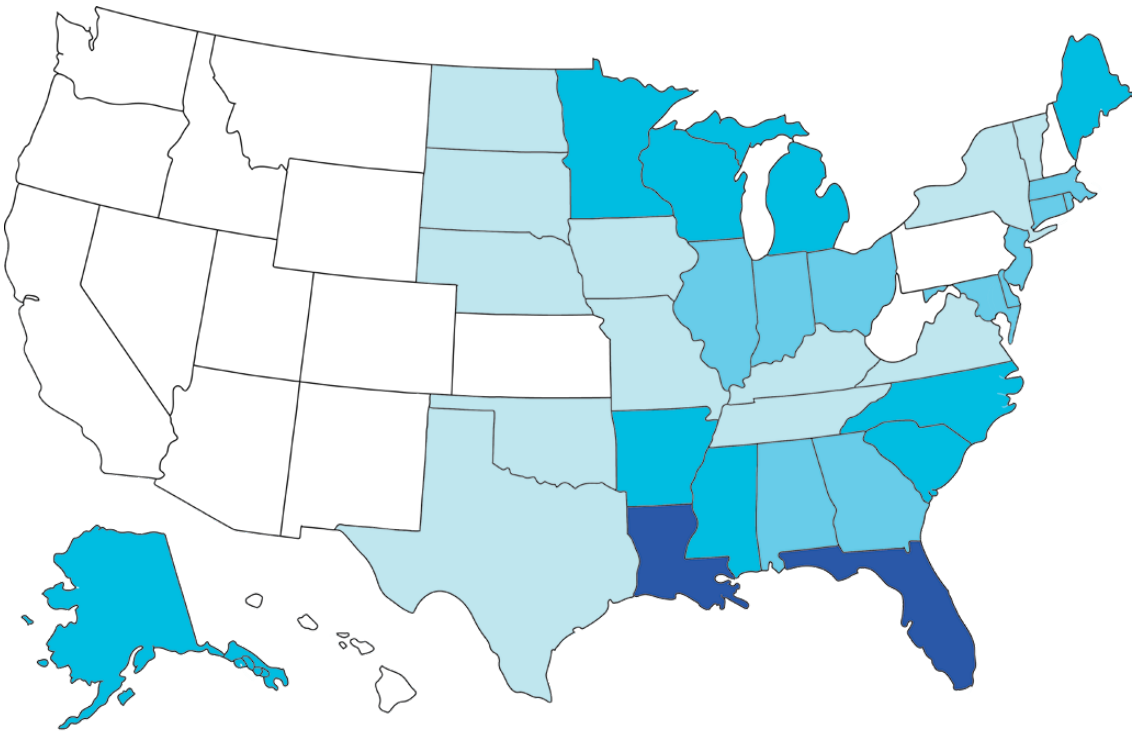
Public perceptions of the role and value of wetlands began to shift during the first half of the twentieth century. After protracted debate, Congress in 1906 passed the Game and Bird Preserves Protection Act, providing regulatory authority for the Bureau of Biological Survey to manage wildlife on designated reservations. The act made it a misdemeanor to disturb birds or their eggs on federal wildlife reservations, including many areas now designated as wetlands. The Migratory Bird Treaty Act of 1918 established federal authority over migratory waterfowl. In addition to establishing protection for enumerated bird species, the act also enunciated the importance of "flyways" and other features of habitat. In the 1920s, hunters and anglers from the newly formed Izaak Walton League organized to fight the draining of large tracts of marsh and bottomlands along the Mississippi River for the creation of farmlands. Drawing on both the observations of outdoor sports enthusiasts and the scientific observations of the day, the league's president wrote, "The Upper Mississippi bottoms are America's most prolific spawning grounds for black bass and for all warm water game and food fishes." Prompted by the league's urging, Congress in 1925 established the Upper Mississippi River National Wildlife and Fish Refuge. Interestingly, the advent of a protectionist outlook for swamplands is associated with the rise of hunting as a leisure-time pursuit, which in turn was enabled by technological developments such as smokeless gunpowder, choked barrels, and the pump-action shotgun.

Even as scientific advances and shifts in cultural value were spurring changes in some areas of government policy, the reclamation imperative continued almost unabated. During the 1930s, the US Department of Agriculture's Soil Conservation Service supported swamp drainage to jump-start the agricultural economy in response to the Great Depression. Owing to the New Deal surge in water resource projects and agricultural assistance investments, fish and wildlife advocates found themselves often in a defensive posture. In 1934, they lobbied successfully for a Fish and Wildlife Coordination Act, which required resource development agencies to consult with the US Fish and Wildlife Service (FWS) during the planning phase of their projects. Though the act and its later amendments did not require development agencies to abide by FWS findings and opinions, it did result in some on-the-ground measures to minimize project impacts, such as construction of fish ladders and other enhancements to affected habitats, including wetlands. In 1947, *The Everglades: River of Grass*, by Marjory Stoneman Douglas, was published, with unmistakable social impact. Although the book provided stimulus for designation of the Florida Everglades as a national park, it did so by making the case that the area was a river rather than "merely" a swamp.

The period from World War II through the early 1960s was the heyday of federal water control projects. Authorized under laws such as the Flood Control Act of 1936 and the Small Watersheds Act of 1956, the Corps of Engineers, the Bureau of Reclamation, the Tennessee Valley Authority, and the Soil Conservation Service constructed almost 5,000 dams and other water control projects, many of which inundated or otherwise impaired wetlands. Enabled through federally sponsored R&D programs in concrete technology, groundwater modeling, and design of large-scale hydraulic structures, this portfolio of government programs resulted in extensive wetland loss.

From 1955 to the mid-1970s, the United States lost

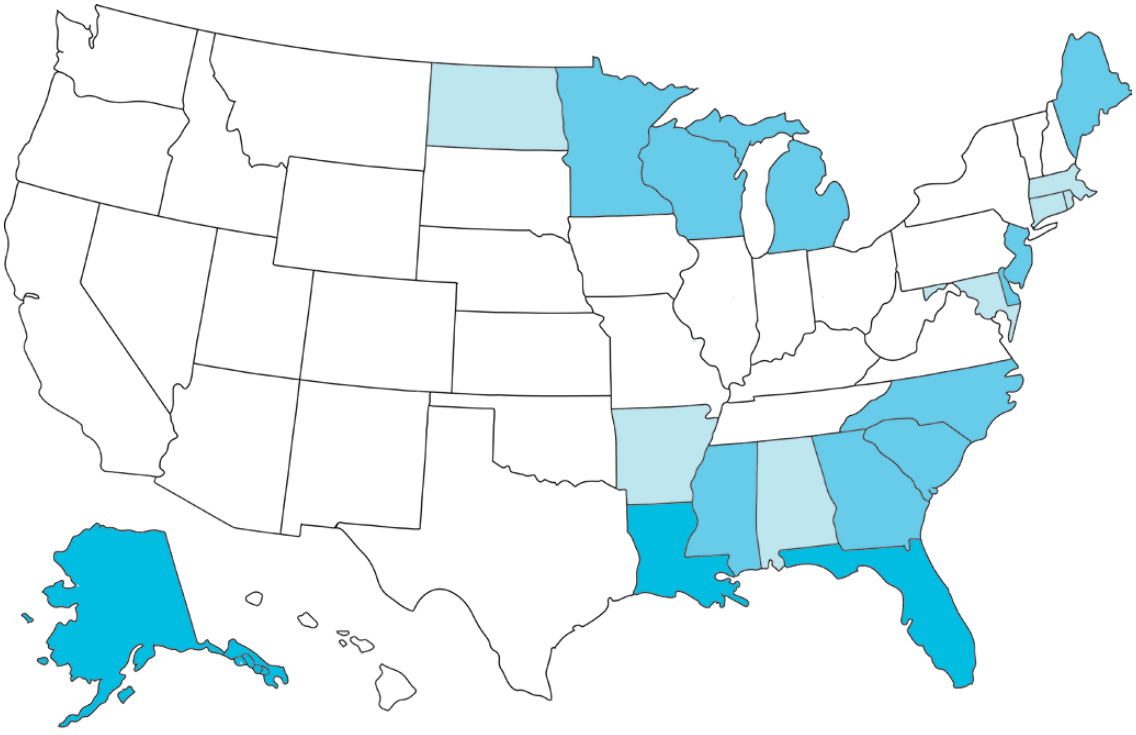
Wetland Distribution Circa 1780s



PERCENT WETLAND

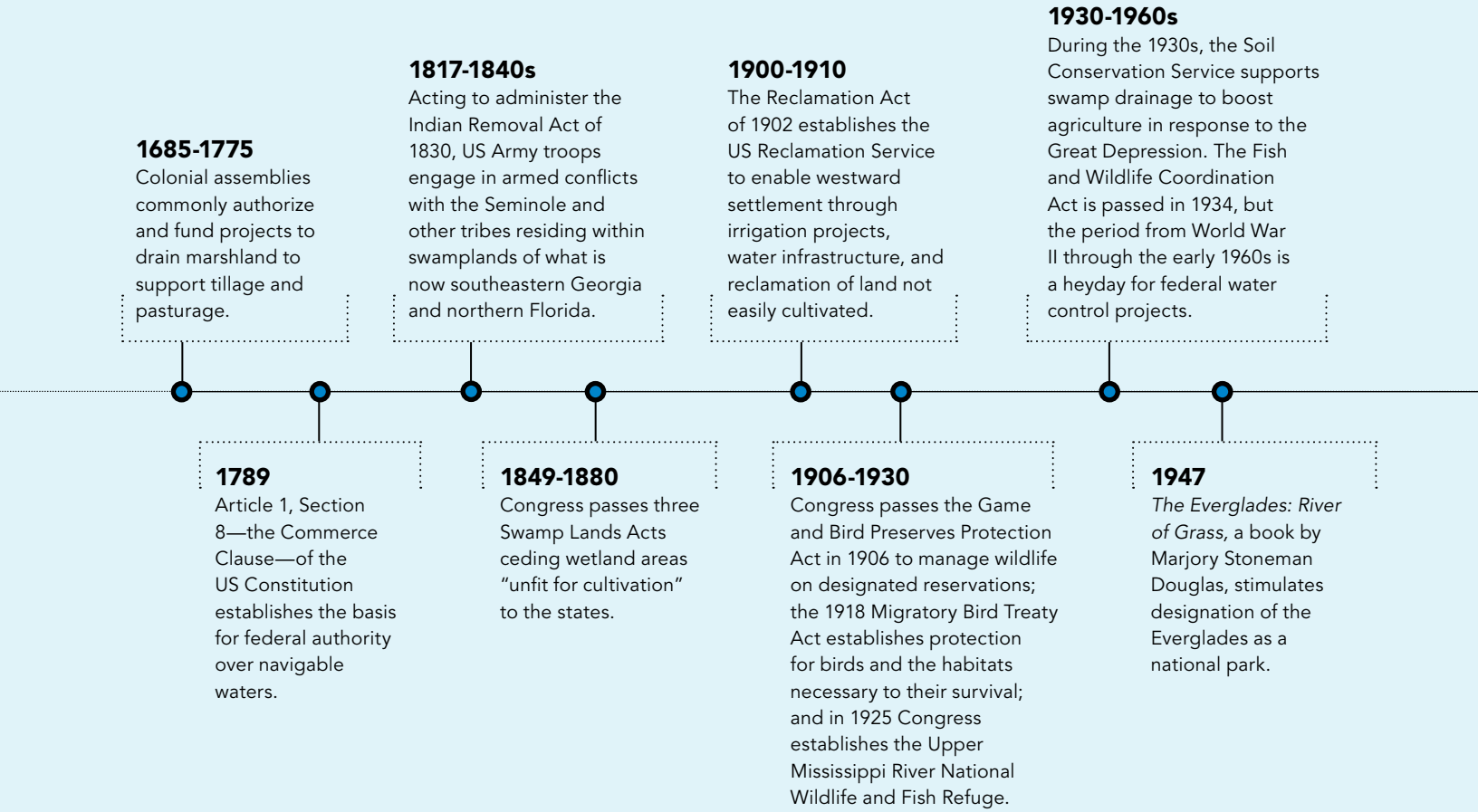
- 1 TO 5
- 5 TO 12
- 12 TO 25
- 25 TO 50
- 50 TO 55

Wetland Distribution Circa 1980s



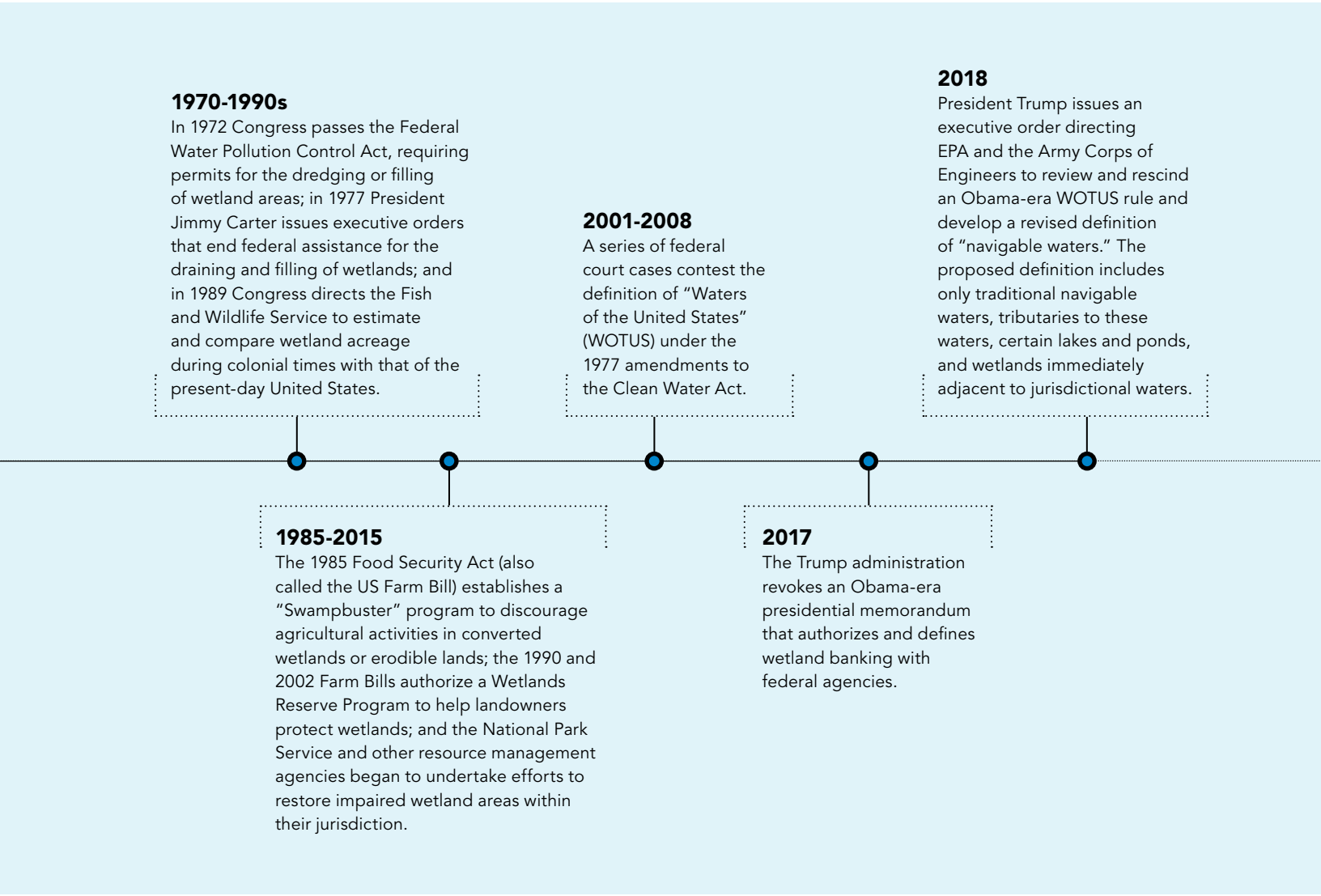
Source: Thomas E. Dahl, "Wetlands Losses in the United States 1780s to 1980s," US Department of the Interior, Fish and Wildlife Service (1990).

A Timeline of US Wetland Policy



approximately half a million acres of wetland habitat every year, most due to agricultural activity. However, advances and consolidation within the fields of wetland science fueled significant changes in public awareness. Indeed, the term "wetland" is a creation of the 1950s, coined partially in response to negative connotations associated with words such as swamp, bog, and mire. Riding a wave of public opinion, Congress in 1972 passed sweeping changes to the Federal Water Pollution Control Act, including provisions requiring a permit for the dredging or filling of wetland areas. Although the Corps of Engineers was tasked with issuance and administration of permits, EPA developed permitting guidelines. In 1977, President Jimmy Carter issued Executive Orders 11988 and 11990, which ended federal assistance for the draining and filling of wetlands in order to avoid or at least minimize destruction of wetland habitat. Another major step in the direction of wetlands protection occurred in 1977, when Congress again amended the Federal Water Pollution Control Act, producing what came to be called the Clean Water Act. Although not articulated in the statute, courts came to interpret the Clean Water Act to include wetlands because they serve as a source of water for US waterways.

In 1986, Congress passed the Emergency Wetlands Resources Act, which authorized purchase of wetlands using Land and Water Conservation Fund monies (removing a prior prohibition on such acquisitions) and directed the Department of the Interior, working through the Fish and Wildlife Service, to estimate and compare wetland acreage during colonial times with that of the present-day United States. The FWS inventory determined that of the original 221 million acres, only 110 million remained by 1980 (see maps on p. 79). Inventory work was enabled by federal research focused on assessment of wetland processes and functionality, which in turn supported development of



wetland classification systems. Outputs derived through research conducted by Lewis Cowardin, Mark Brinson, and others was institutionalized in the form of a National Wetland Inventory. More generally, wetland classification work was supported through access to government-funded drainage statistics, land-use conversion data, hydric soils databases, digital-spatial analyses, and other sources of historical wetlands data. Building on these research activities, the Office of Management and Budget in 2003 released Circular A-16 providing guidance on development and upkeep of a National Spatial Data Infrastructure to include regular updates of the National Wetland Inventory.

In 1985, Congress enacted the Food Security Act (also called the US Farm Bill) establishing a "Swampbuster" program to discourage agricultural activities in converted wetlands or highly erodible lands. Critically, the Food Security Act also guided future protection of wetlands through promulgation of field criteria for the delineation of wetlands. A year later, the United States signed on as a party to the Ramsar Convention of Wetlands of International Importance, a decade and a half after its establishment in 1971. The Ramsar Convention calls on parties to recognize the services provided by wetlands and to designate wetland areas of "national significance." Starting at around the same time, the National Park Service and other resource management agencies began efforts to restore impaired wetland areas within their jurisdictions. Many of these restoration projects included removal of fill material, ditches, artificial levees, and berms constructed as part of earlier efforts to reclaim the very same wetlands. Later Farm Bills adopted in 1990 and 2002 expanded on the 1985 Swampbuster program by authorizing a Wetlands Reserve Program, directed by the Department of Agriculture's Natural Resources Conservation Service, to help landowners protect wetlands and recoup value lost through subsequent lack

of agricultural utilization.

By the 1970s most federal policies dealing with wetlands had shifted away from out-and-out reclamation and toward a mix of scientific management, protection, and even restoration. Though never codified in statute, the principle of "no net loss" has been embraced and operationalized by all presidential administrations since George H. W. Bush. Although different administrations have interpreted this policy in different ways, the basic articulation has always honored the premise that wetlands should be protected and, if lost or degraded, replaced through the creation of new wetlands in the same general area. Nevertheless, this policy and management consensus has been subject to challenge through a series of federal court cases and corresponding agency directives addressing the definition of WOTUS under the 1977 Clean Water Act. The 2006 US Supreme Court decision in *Rapanos v. United States* is especially important because inconsistencies among the justices resulted in confusion regarding the basic applicability of the Clean Water Act. In the late 1980s, a Michigan developer named John Rapanos filled a 22-acre wetland in order to build a mall without filing for a permit, claiming that the property was not a wetland. After an initial guilty verdict, the case moved through a series of remands and reinstatements before being argued in the Supreme Court. Leaning upon a farcically textualist interpretation of the Clean Water Act, Justice Scalia's plurality opinion sidestepped the corpus of wetland science and characterized the Corps of Engineering's practice of regulating intermittent waterways as "useful oxymora" and opined that WOTUS should include only "relatively permanent, standing, or continuously flowing bodies of water." Uncertainty created by *Rapanos* and other court rulings in turn prompted the Obama and Trump administrations to develop revised interpretations of WOTUS within the context of the Clean Water Act.

Clarity and complexity

The press release accompanying EPA's publication of the Trump administration's proposed WOTUS Rule celebrates the advent of a "simpler and clearer definition" and asserts that the new policy will result in "cost savings" and "substantial economic growth" and "reduce barriers to business development." Though clearly aspects of good governance, the imperatives of regulatory simplicity and clarity of application are no justification for policies that are blind to complexity or that assume a world that is different from the state of scientific understanding. For the past two decades, US wetland policy decisions have been founded on a body of research that demonstrates that the connectivity of streams and wetlands is not determined solely by proximity and continuity, but also by overland flows, evapotranspiration, subsurface flow regimes, biological dispersal mechanisms, and other site-specific factors. Whether permanent or ephemeral, wetlands function as sinks for floodwaters, sediment, nutrients, and contaminants that would otherwise affect the condition of downstream waters. The proposed WOTUS Rule seems not to account for the fact that wetlands are dynamic systems that change over time, that the incremental contributions of individual wetland areas can be cumulative across entire watersheds, or that some wetlands are often subject to nondevelopmental stressors such as flooding, erosion, and wave action. Flood plains, wet prairies, forested bogs, mangroves, arctic wetlands, salt marshes, and peatlands differ in terms of soil, surficial attributes, and hydrologic regimes, resulting in different habitat characteristics and thus requiring different management approaches and restoration techniques. The research portfolio makes it clear that wetlands cannot be effectively managed as if they were a set of interconnected surface water features.

The current regime of policies addressing wetlands is broad, ambiguous, and suffers from inconsistent application, especially if one considers state and local jurisdictions.

Although sparsely covered in the popular media, President Trump's action to rescind Clean Air Act regulations also struck a blow against the scientific management of wetland resources. The March 28, 2017, executive order that rolled back the Obama Clean Power Plan also revoked other standing presidential directives, including a 2015 presidential memorandum that authorized federal agencies to undertake and support the practice of wetland mitigation banking. Wetland banking is key to the operational viability of the no net loss policy because it makes it possible for landowners to restore, create, or protect nearby wetland areas to compensate for wetlands lost or impaired during the course of development. This action portends unfortunate consequences on at least three distinct levels. First, it hampers our ability to manage present-day wetland resources in a rational and efficient manner. Second, it limits our ability to use—or rely on—wetlands as a mechanism to sequester carbon, and hence, help mitigate climate change. And third, it will make it harder for us to restore and replace wetlands likely to be lost or degraded due to the effects of climate change.

As the environmental historian Ann Vileisis has written, wetlands have long vexed policy-makers: "Traditionally, land has been considered as private property and water as public property—because wetlands are not only land but land *and* water, regarding them simply as real property with no other consideration has been a fundamental error in paradigm." Most of the nation's so-called wetland policies do not really target wetlands per se, but rather address wetlands in terms of their potential impact on other areas of public value, most particularly clean water and the sanctity of private property. The current regime of policies addressing wetlands is broad, ambiguous, and suffers from inconsistent application, especially if one considers state and local jurisdictions in addition to policies at the federal level. Moreover, many policy initiatives in recent years have been based on executive actions driven by ambiguous legal rulings and not founded on the bedrock of strong and clear statutory language. Yet it is fair to say that if implemented, the proposed WOTUS Rule would constitute a reversal of the historical arc of US wetland policy.

It may be time for a focused, omnibus package of wetland management and protection legislation. Aspects of wetland policy that should be provided with a statutory grounding include the following:

- Codification of the principal of no net loss, including a requirement for federal agency application and implementation under a defined schedule. In the past, no net loss has been a policy goal, but not a legal requirement operationalized in terms of specific wetland functions. Under such a program, wetland services, not merely acreage, would be expressed in terms of metrics monitored and verified through regular, standardized inventories.
- Authorization and codification of processes and administrative mechanisms for wetland banking and trading at the federal level. Although at least 17 states or special jurisdictional units (e.g., port authorities, water utilities) provide a legal basis for various wetland transactions, activities on the federal level are cobbled together through biparty memorandums of understanding and other situational agreements that lack a coherent mission and mechanisms for regular congressional oversight. A government-wide program of wetland banking and trading would forge greater consistency and accountability in wetland-related applications.
- Stipulation of controls over the assignment of wetland oversight to state or local agencies. Similar to EPA's oversight of state-level air quality and drinking water safety programs, wetland oversight could be granted to states, municipalities, or counties only if they maintain conditions of primacy, such as adherence to nationwide standards, delineation methods, and certifications. This would help to lend consistency and accountability to the management of wetland resources.
- Continuation of the National Wetland Inventory process, with a mandate for a five-year assessment and reporting cycle. The current inventory cycle is decadal. Reduction in cycle-time would provide improved data and better support adaptive management of a no net loss management regime.
- Authorization and funding for private-sector and nonfederal wetland restoration. This could be accomplished through existing mechanisms such as the Land and Water Conservation Fund and the National Fish and Wildlife Foundation.

The enduring health and vitality of the public's wetland resources should not be subject to the whims, ideological caprice, or stakeholder relationships that influence the actions of US presidents. Rather, they should be stitched into the fabric of statutory law, possibly through amendment of an existing vehicle such as the 1986 Wetlands Resources Act. Though the current reality of partisan gridlock may dim the prospect for passage of an omnibus wetland protection and management statute, legislation could be crafted to address the needs of a diverse array of stakeholders, including advocates of ecological stewardship; hunters, fishers, and other outdoor sports enthusiasts; municipalities concerned with source water protection; agricultural producers; and landowners and developers. Indeed, a suite of policies focused on wetland protection, restoration, and creation could serve as a tangible pillar for a Green New Deal.

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Recommended reading

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STEPHEN J. MILLER

WHAT DO PATENTS MEAN?

In today's corporate environment, patenting may have little to do with innovativeness.

A few years ago, I met with a group from a company interested in a technology I had developed and my company had patented. After the standard niceties, followed by a technical discussion, and then lunch, I could now get to the point of the meeting. I asked the manager of the visiting group whether their company was interested in licensing my technology. "Why should we take a license to your company's technology," he replied, "when our competitors are already using your technology for free?"

That exchange encapsulates much of the reality of patenting today. If patents were once seen as a powerful policy tool for incentivizing invention, today their value and role are complex and ambiguous. If a company is unwilling to strongly defend its patents in court—and many are not—then isn't that company undermining its own investments in technology development and in the researchers who devote their talents to this work?

The basic idea behind patents is that they encourage innovation by giving an inventor protection for an invention for a substantial number of years. This being the case, a good metric of a company's innovativeness ought to be the number of patents it receives. But the first thing to know about patents is that although they confer the right to block someone else from using your technology, they do not confer an obligation on you to use the patent. So if a company files for a patent, that doesn't mean it intends to develop, commercialize, or defend the patent against infringement. Indeed, after 42 years in industrial R&D, drawing on my own experience inventing and patenting new technologies in a corporate setting, and working with a number of companies, universities, and technical organizations, I have come to question the value and meaning of patents.

We have met the enemy

Let's start with the degree to which patents encourage innovation. (For this article, I'll define innovation as something new that is used in the marketplace, in contrast to invention, which I'll define as something new but not necessarily commercialized.) When a researcher working for a particular company finds something new in the laboratory that could improve a technology already patent protected by that company, filing a patent application can protect the improvement against a competitor, broaden patent coverage in that technology space, and give the company further protection in case the validity of prior patents is challenged. Or, if that researcher discovers an improvement on a technology owned by a competitor, for example a new application for an existing process or a way to reduce the cost of the process, filing a patent application can block the competing firm from making that improvement, inhibiting innovation in that space. Improvements on a competitor's patent can also help gain access to that technology through a cross-licensing agreement. It's in this context of competition between firms that we often think about patents.

But perhaps the more interesting case occurs when the researcher finds something new that could lead to a technology that would directly compete with technology already owned and marketed by the company where he or she works. One might think that this would automatically be good news, and that the new technology would be patented and commercialized as quickly as possible. Yet competition occurs not only between companies, but within them as well, and anyone (from researchers to marketers to executives) who has a major vested interest in the currently commercialized technology (including their very jobs)

may well oppose a new technology that threatens to make the old one obsolete, even if the change would benefit the company's bottom line. Vested interests also may include large investments in capital equipment, supply and distribution chains, marketing, and the know-how associated with long experience producing an incumbent technology. For example, think about the companies whose businesses for decades revolved around photographic film, and the internal vested interests that would have to be overcome in switching their emphasis to digital photography. In fact, this was exactly the story for one of the nation's great high-tech corporations, Kodak, which invented the digital camera and patented it in 1977, but viewed it as a threat to its business model, and ended up filing for bankruptcy in 2012. As Machiavelli noted in *The Prince* some 500 years ago, "The innovator has for enemies all those who are well off under the existing order of things, and only lukewarm supporters in those who might benefit under the new."

In my experience, it's far more difficult for a researcher to move an innovation forward when it competes with technology already owned and used by that researcher's company than when it does not.

Yet this brake on innovation is difficult to see from the outside, and insiders are understandably reluctant to acknowledge what is happening. Indeed, a firm's executives can offer a number of seemingly logical reasons for why the new technology should be patented but should not be pursued. One standard excuse is that resources are insufficient to adequately bring the new technology to commercialization. In some cases, that may be true, but often that is because management is reluctant to move resources away from the existing technology, which may be profitable, to something that is less certain, even if economic evaluation shows it to be a likely winner. This tendency may be reinforced in many firms today because the individuals responsible for making decisions on new technology often gain their position by successful cost management, but they do not know how to bring a new technology to market. It should be no surprise, then, when such managers end up prioritizing cost management over innovation.

Another standard excuse for not adopting a new technology is to claim that it is economically inferior to the current technology. But such comparisons are always problematic. Any technology in its earliest phases can easily be shown to fare poorly in a technoeconomic evaluation that compares it with a well-established technology that may have been optimized over many years. Because of the uncertainty around the new technology, the engineer doing the assessment can assign the new technology a large "contingency factor" in the evaluation, usually large enough to make it look worse than current technology. A contingency factor is an added cost multiplier that the cost estimator uses to cover unforeseeable expenses the project may incur. If the project is then dropped, the validity of that contingency will not be challenged by further development.

New technologies I worked on were typically assigned contingencies of 50% or more, a large handicap right from the start. In addition, I was almost always required to show an internal rate of return for the investment of at least 30%, when most projects that were being commercialized had a rate of return far less. These sorts of technoeconomic assessments usually start out strongly biased toward the incumbent technology. Indeed, evaluations are often done not to determine whether to pursue a new technology, but to justify shutting it down, ostensibly to save money that some parties argue would be better spent making incremental improvements to the current technology. Moreover, typical corporate technoeconomic evaluations focus on metrics that make the current technology look good, rather than those that could give the new technology an advantage. Consider, for example, the introduction some years ago of cameras in cell phones. If the companies that introduced this innovation had assessed the cameras by picture quality, they would of course not have matched a decent 35mm camera. But if assessments also took size, portability, and ease of use into account, the balance would have shifted—a perspective that the marketplace has decisively endorsed.

Even if a technology does not directly compete with a firm's current technology, it may be seen by vested interests within the company as a competitor for resources. In such cases, a typical excuse for not pursuing the technology is to declare that it is outside the company's "core" business. In such cases, the uncertainties of development and commercialization would justify even greater technoeconomic contingency factors, again supporting continued focus on existing technologies and acting against innovation even if the new technology is patented.

Inventors but not innovators

The tendency of many companies to patent and then bury new inventions might be less of a problem if corporate scientists and engineers were free to develop unwanted inventions independently, or to look for another company to carry the technology forward. But the first day on the job for researchers in technical industries usually includes them signing over to the company the permanent rights to anything and everything they discover or invent while an employee. This can even include ideas totally unrelated to the job assignment, so long as the company can claim the individual came up with, or developed, the idea on company time. Under this arrangement, patents will list the actual inventor, but all rights are assigned to the company, and if the company decides not to pursue development or

commercialization of a technology, the inventor has no recourse. I've certainly had this experience. Some years ago, I developed a technology for which my company acquired several patents. When I was told that the company had decided not to commercialize my invention, I asked if I could buy back the patent rights to that technology. The answer was no. In fact, even if a company abandons a patent, it can still prevent an inventor from doing anything with the technology since the company can accuse the employee of theft of confidential company information—even if the patent already disclosed to the public all information that would otherwise be considered confidential.

The loss of ownership of their discoveries and inventions obviously reduces the negotiation leverage of inventors when it comes to compensation and other benefits. It also allows companies to lay off inventors without the fear of them taking what they know to a competitor. Perhaps less obviously, these standard business practices undermine the inventor's ability to advocate for her or his invention within the company, thus elevating the potential for the invention to be stifled by others in the company whose interests it might threaten. In this way, innovativeness, potential business growth, or long-range benefits to the company's customers may actually be sacrificed.

Of course, burying new technology is not as easy as it once was. Published US patent applications and patents are carefully monitored by a growing list of countries with sufficient resources, both people and facilities, to copy and commercialize the technology to the detriment of the company holding the US patent position and to the detriment of US innovation in general. Even if the company has obtained patents in other countries, these may prove ineffective, especially if the countries where the technology is developed or marketed has limited patent protection laws. Consequently, burying the technology may be a less accurate description of some corporate patent practices than setting it aside for foreign players to benefit from.

Honored in the breach

Even if a company is serious about developing a product that one of its scientists has patented, it doesn't mean that the company will then enforce the patent. Yet filing a patent that is not enforced amounts to educating the competition for free. Infringers will seldom go out of the way to inform a patent holder that they are using his or her invention, so being serious about enforcement means having the people in place who are responsible for determining whether company patents are likely being infringed, a process made all the more difficult by the globalization of innovation capacity. With many competitors now residing in countries outside the United States, information about what competitors are doing is often hard to come by, and patent enforcement in those countries may be weak at best—even if patents are also filed in them. In some countries, such as China, customers for US technology may insist on a patent being filed in that country before they will license the technology. Since the chances for enforcement of the patent there are slim at best, this requirement may be more intended to give the customers more in-depth knowledge of the technology so they can copy it for their own use. Although this practice may enhance innovation in China, it certainly doesn't help advance US innovation, particularly if the licensee then proceeds to market the technology in countries where the US patent holder also markets, or would like to market, that technology.

In all cases I was involved in regarding licensing to Chinese companies, these factors were lightly regarded by my company, since management performance was judged much more on current income than potential future income.

Even if a likely infringer of a patent has been identified, companies may decide to take no action for several reasons. One is that the cost of litigation can be high, where the chances of success are uncertain, and where that cost and risk can be justified financially only in a limited number of instances. More often, companies may simply offer the infringer a license to the invention. The infringer will then have to weigh the cost of that license against the possible cost of being found guilty of infringement in court, where a principal factor in that calculation will be the known aggressiveness of the company whose patent they are infringing. For companies with a history of not enforcing their patents, more than likely the offer of a license will be ignored.

For example, early in my career, I developed an oil refining technology for which my company was awarded a patent. Several years after that, I became aware that another company was offering to license a technology that I was fairly sure infringed my patent. That company was also opposing my patent in Europe, where revocation of my patent would have allowed the company to freely license its competing technology. I was able to convince my company to defend against the opposition to our European patent, which we did successfully. I then expected my company to go after the other company for damages. Instead, mainly because our company was concerned about the costs and uncertainty of litigation, it simply asked the other company whether it wanted to take a license. The answer, of course, was no. Not only did my company's failure to pursue damages nullify any benefit that might have been obtained from successfully defending our European patent; it also taught the other company that it could then proceed to infringe other patents of mine with impunity, which it did over a number of years afterward.

Another reason a company may take no action against a likely infringer is that the company already has an existing

TO PATENT OR NOT TO PATENT?

Given the complexities of real-world patenting practices, the costs and benefits of patenting are not always clear. Here are some of the uncertainties facing an inventor deciding whether or not to pursue a patent.

- Many inventors and companies assume that if they obtain a patent, it will be effective for 20 years after filing. But since patents are usually filed very early in the development history of a new invention, there often is no financial return for several years or more. Meanwhile, filing and maintaining patents can be expensive, especially if one seeks protection in multiple countries, typically amounting to between $10,000 and $25,000 per country per year. When corporate managers want to control costs, it is not surprising if they choose to abandon patents that cannot be justified financially, particularly during a business downturn. Consequently, it's also not surprising when management, some years later, tries to assert a patent against a competitor only to find that it is no longer in force. The actual life of a patent, then, can be quite short, greatly reducing the patent's benefit.

- The American Inventors Protection Act, adopted by Congress in 1999, requires that most patent applications be published 18 months after filing, in order to be more consistent with European patent law. A principal objective of this requirement is to prevent users of an invention from being sued for infringement under a "submarine patent" that has been hiding in the Patent Office for years. But this requirement also means that an invention is made public before the inventor knows whether or not a patent will actually be granted. In cases where a patent is not granted, the inventor winds up disclosing the invention with no protection for it at all, even if the invention is novel and nonobvious, the two main requirements for a patent.

- If an inventor or company does not mind an invention being known to the public, perhaps because they want to use the patent only to prevent a competitor from patenting the invention, they only have to file the patent application so that it will be published by the Patent and Trademark Office. This action is sufficient to serve as a reference ("prior art") against anyone else attempting to patent the same thing. An even less costly option would be to publish the invention in a well-known technical journal. But this can be risky because patent examiners may not search thoroughly for prior art outside of US patents and patent applications, and so may easily miss prior art published in the academic literature.

- On the other hand, sometimes patent examiners can make the opposite type of mistake. Indeed, with the high turnover of examiners in recent years in the US Patent Office, it is not unusual that a patent application is assigned to an examiner who has considerable difficulty in understanding the invention being claimed. I once had a patent application for an organic synthesis rejected by the examiner because he asserted it was obvious, although he was unable to find any prior art supporting that assertion. He claimed that because he was educated in physics, he didn't need to show prior art—the synthesis seemed obvious to him.

- Collaboration with universities raises its own set of patenting challenges for private firms. Because timely publication is a critical requirement for collaborating faculty, universities will typically insist that no restraints be placed on publishing. Such requirements are not a problem if patent applications are filed promptly before publications are submitted. But faculty often want to submit results for publication well before any work is done on the actual invention. A prior academic publication may only hint at the possibility of the invention, yet it can then become a prior art reference against any patent application. Such a reference can severely limit the allowable claims in any further filing. Given the appropriate culture of openness in academia, such leakage of confidential information is difficult to control. Companies may therefore decide to limit collaboration with universities to nonproprietary research aimed at fostering good relations and identifying promising candidates for future employment, but such tensions may be yet another obstacle to valuable innovation.

or potential relationship with the infringing company, often in another sector or sectors of business, as a partner, a customer, or a supplier. If the real or perceived value of that relationship is greater than the estimated value of the invention, which in its early stages is usually quite uncertain, then the patenting company may choose not to go after the infringer. I saw this happen at a time when my company was negotiating a business deal with another company that I was confident had been infringing one of my patents. Our management decided the value of the deal being negotiated was greater than the value of the technology under my patent, so they refused to try to enforce it. This may or may not have been a sound business decision, but it certainly provides another example of how disconnected the practice of patenting has become from the pursuit of innovation.

Besides undercutting the intent and value of patents, these sorts of practices may also have the unintended consequence of reducing corporate investments in research, since such investments are typically justified on the basis of the income they generate. Failure to defend patents automatically reduces the income generated by research, and thus justifies reductions or even elimination of research investments, a completely self-defeating cycle of poor innovation practice.

The proper measure of innovation?

The number of patents granted to a company is often taken as a measure of innovation. A recent article in *Issues in Science and Technology* by Geoffrey Funk ("Beyond Patents," Summer 2018) showed that patent databases are poor tools for understanding and analyzing innovation. I've tried to provide an insider's perspective on some important reasons why patenting may not say much about innovation, and how the value of patents may be reduced or completely negated through internal company politics or through a weak commitment to enforcement. These problems, which in my experience are quite common in at least some technological sectors, mean that a firm's patenting activity may be a very weak indicator of its innovativeness.

In reality, number of patents is a better measure of the size of a company's budget for filing patents than it is of innovation. Indeed, there might be a large burst of innovation within a company when business is in a downturn and budgets are tight. In this case, patent applications may be filed only in a very select number of instances, or not at all. There may even be an effort to cram as much as possible into a single application, which in better times would be spread over multiple applications. In my own experience, during one stretch of my most productive years, filing for patents was strongly discouraged due to pressure to reduce cost. Consequently, important technology was poorly protected, and the opportunity to gain strong coverage lost. Likewise, there might be little true innovation occurring when funding for patenting is high and both the technical staff and attorneys who write patents are rewarded for number of patent applications filed regardless of their value to the company or merit. Managers may even budget for a specific number of patent applications in their area in order to use that number to help justify their R&D budget to upper management, whether the inventions being patented have real value or not.

In other cases, a company may want a large number of patents on various aspects of the same invention to help protect that invention against attack via challenge of a single patent. It may also want a large number of patents in an area it believes a competitor is working, not because it intends to develop or market any of the inventions, but to block that competitor, possibly to create an item of trade in a cross-licensing agreement.

Finally, patents may vary radically in terms of their plausibility and potential value. As I've mentioned, many patents may be granted for minor variations of the same invention. This is quite different from patents on several distinctly different inventions. But even patents on distinctly different inventions may be of radically different quality. For example, patents that tell how to make the invention without actually having done it are especially uncertain, and may signal that the perceived value of the invention is not enough to justify the cost or time of carrying out a trial. The value of patents that show only partial steps in the invention should also be viewed skeptically, as should patents of inventions that do not show a surprising benefit versus the prior art. Inventions demonstrated at pilot scale are better than those tested only at small lab scale, because larger scale signals both reduced commercialization uncertainty and greater commitment to develop the invention.

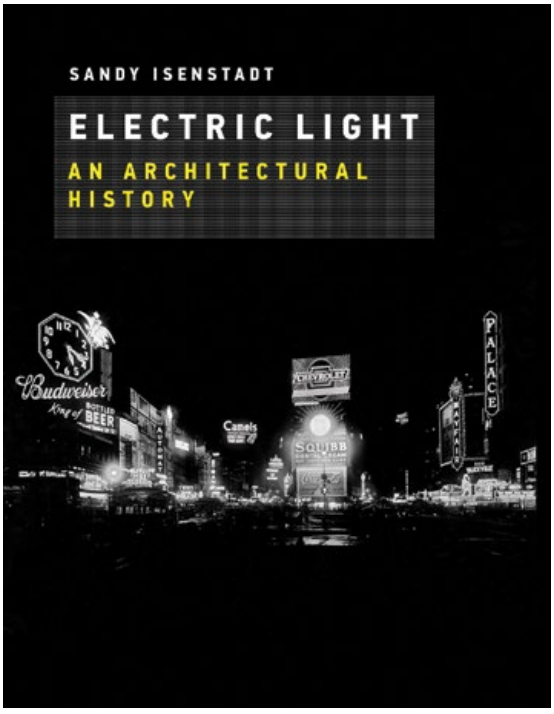
But most importantly, as I've been emphasizing here, since private-sector innovation is best understood as creating something new that is used in the marketplace, counting patents to measure innovation would start to make sense only if patents were almost exclusively on products and processes actually in the marketplace. As we have seen, that is often not the case.

That patents encourage innovation may have been largely true in an age where most patents were owned by their inventors. Today, when most inventors have no ownership or control over their inventions, that assumption needs to be reexamined. The United States needs to recognize that its most innovative companies are not necessarily those that have the most patents, but are those that are most successfully growing new businesses and business lines on the basis of technologies that they develop internally. If the nation is to understand how well its companies are innovating, it will need to take a much more realistic approach to understanding the complex and often contradictory role of patents.

Stephen J. Miller *spent more than 40 years as a research chemist in the oil industry. He has more than 250 US patents.*

The Medium of Modernity

TAYLOR STONE



Electric Light: An Architectural History
by Sandy Isenstadt. Cambridge, MA: MIT Press, 2018, 304 pp.

Artificial illumination occupies a paradoxical position in modern daily life. It is a ubiquitous technology, pervading almost every interior space and shaping nighttime environments. Yet despite (or perhaps because of) its omnipresence, artificial light remains in the backdrop of daily life, rarely noticed or appreciated. As a quick exercise, try counting and categorizing the number of lights you pass on your next evening commute. The totality of lights—streetlights, porch and security lights, light shining out from homes and office windows, vehicle headlights, traffic signals, billboards, shop signs, and digital screens, to list but a few—creates a seemingly inescapable sea of artificial illumination within which we now live. In *Electric Light*, the architectural historian Sandy Isenstadt brings attention to the generative force of artificial illumination, and electric lighting in particular, through detailing its complex social history and the various ways in which it has shaped modern life. By drawing attention to the profound influences of electric lighting over the past century, Isenstadt posits that it can be understood as the very medium of modernity.

Isenstadt convincingly presents his argument at the outset, explaining that artificial light "was as fundamental to the making of the modern world as any system of transportation, communication, or energy and as momentous as industrial urbanization itself." It is a technology fully intertwined with the social, economic, and spatial experience of the twentieth century. Yet he also goes a step further, explaining that artificial illumination, and electric lighting in particular, created a new way of understanding, experiencing, and inhabiting the world—what Isenstadt terms "electric modernism." This is the central idea weaving the book together, and Isenstadt investigates the concept through explorations of how, where, and why electric illumination came to shape modern spaces, perceptions, and behaviors.

Electric Light is a fascinating read about the sociocultural impacts of illumination, offering insights for those with a casual interest in lighting, as well as folks (such as myself) in the deep end of artificial light as a niche research subject. And it includes a wealth of photos, paintings, and diagrams that bring a further degree of richness to the text and serve to illustrate the central narrative. The book limits its analysis to the early decades of electrification and the introduction of electric lighting, roughly the late 1800s through the mid-twentieth century. The body of the book is composed of five chapters—covering the light switch, nighttime driving, factory lighting, advertising and billboards, and World War II blackouts—each providing an in-depth case study examining an aspect of how electric light has shaped modern life. Although each chapter explores and reinforces the book's central idea of electric modernism, there isn't a continuous narrative. Further, as a thorough historian, Isenstadt includes a wealth of interesting but somewhat trivial (and occasionally tangential) historical details. I suggest that readers feel free to pick chapters—or even chapter sections—based on their own discretion and interests, as this should not detract from the quality of insights Isenstadt provides.

That said, the chapters effectively combine to clarify the multifaceted idea of electric modernism and the extent to which electric light has permeated modern life. The first case tells the story of the light switch—a seemingly mundane invention, but one that helped to domesticate electricity. In the late nineteenth century, electricity was still a mysterious and powerful force outside ordinary experience. The switch gave the average person dominion and mastery over electric light, and thus a new level of control over the illumination of spaces. The ramifications were far-reaching, changing domestic habits (e.g., eventually the switch came to replace

various household chores), reinforcing gender biases regarding technological literacy (e.g., women were supposedly "confused" by switches and had trouble adapting), and creating a new form of political theater (e.g., the public lighting of a Christmas tree or opening of an exposition).

In analyzing the lasting influence of the light switch, Isenstadt frames its effects via the philosopher of technology Albert Borgmann's "device paradigm": for all its magic and convenience, the light switch also separated the commodity (illumination) from the production and processes that create it. We now have access to illumination "at the flip of a switch," with little regard to or knowledge about how it works or what powers it. In this way, Isenstadt shows how a seemingly benign innovation—the light switch—alienates people from technological processes and functions endemic to modern, urbanized life.

The next two cases explore the connection between electric lighting and other shapers of modernity, namely the automobile and the factory. First, Isenstadt shows how the intersecting inventions of electric lighting and cars created an entirely novel activity: night driving. This is placed on par with cinema as the two most important novel visual experiences of the early twentieth century. Alongside this new aesthetic experience, night driving required novel laws and regulations. It spurred new fields of research (and public concern), such as the health issue of "dazzle" caused by glare, or safety standards linking braking time to headlight visibility. But at a more profound level, night driving created an unmistakably modern way of experiencing the world at night. Indeed, Isenstadt points out that through learning to manage this conglomeration of new technologies, and learning to understand the world presented via headlights, we became modernized in the process.

Isenstadt next elucidates the formative influence of electric lighting on factories—another driver of modernity. It is easy to forget that before efficient and bright artificial light, working at night was much more difficult and carried out only when necessary. Electric lighting did what neither natural light nor previous forms of artificial light (candles, oil, or gas lighting) could: provide a consistent, uniform, safe, and reliable source of illumination adequate for manual labor. Factories were effectively freed from the operational and design constraints of natural lighting, and instead could be organized for efficiency in the production process. And like all other processes aimed at efficiency, lighting, too, was studied and optimized. A well-lit workplace was eventually incorporated into standards and laws, and even took on a moral valence: better lighting was good for workers, the company, and even society as a whole.

The fourth case looks at a specific form of electric light in the public realm: advertisements and billboards, or what Isenstadt refers to as "electric speech." The chapter focuses on New York City's Times Square as the original site and continued reference point for electric speech, which created a new type of urban nightscape awash in a sea of illuminated advertising. Isenstadt shows how this illumination is distinctly modern and distinctly American: forward-looking, boisterous, and unapologetically capitalist. Eventually, electric speech spread around the United States and the world, linking capital and commerce with urban identity in a practice that continues to this day in downtown "entertainment districts." Yet however powerful and provocative these spaces may be, they are also devoid of anything beyond their surface purpose of pushing products—arguably emblematic of a superficiality found throughout modern culture.

The book's final case looks not at electric light itself, but at an instance when darkness was temporarily reintroduced: during blackout drills in the United States in the lead-up to and during World War II. Not strictly necessary away from the East Coast (where city lights could silhouette ships and make them vulnerable to German submarines), blackout drills to stymie aerial bombing were still practiced throughout the country. With these, people had to literally relearn how to understand and navigate spaces in darkness, revealing how normalized electric light had become just a few decades since its invention. Interestingly, this also gave new meaning to darkness during blackouts—not as dangerous, but instead as protective. Further, adapting to the darkness became an act of patriotism, a collective will to overcome the darkness of fascism. Americans could endure darkened cities because of the "inner light" of their values. In this sense, explains Isenstadt, electric lighting had come to be identified with national character.

By drawing out the moral and political discussions within *Electric Light*, we can find various insights that deserve further reflection—for example, the gendered nature of lighting; or the links between electric lighting, labor, and capitalism; or the complex intertwining of artificial illumination with evaluations of darkness. Further, the enduring resonance of electric modernism is something we still live with today, and that continues to shape our experiences of the world at night. Much of what is presented in *Electric Light*—flipping a light switch, driving at night, electric speech—has become so normal in daily life that it seems natural. But Isenstadt does an excellent job of revealing the complex origin and history of these practices, and the lasting influence they have on our perceptions and experiences.

Taking inspiration from *Electric Light*, I would like to offer a brief thought experiment. Imagine that an architectural historian, working 100 or so years from now, embarks on an ambitious project to analyze the ways in which lighting influenced the twenty-first century. Artificial illumination

will surely continue to shape (post) modern life, but in what direction? We are currently in the midst of a major lighting revolution, with solid-state lighting (namely, light-emitting diodes, or LEDs) harkening in a new age of lighting. There is a great deal of excitement over this new technology, and a rapidly increasing adoption for indoor and outdoor lighting. LEDs offer many benefits, such as efficiency and controllability, but scientific studies and advocacy groups have raised concerns about their long-term ecological and health effects, their contributions to "skyglow" and other types of light pollution, and even their realizable energy-savings.

So what will our historian find? What social and political forces will guide the adoption of LEDs, and vice versa? Will they have served narrow commercial interests, or a broader range of social and environmental values? Will they have provided a means to curb light pollution, or exacerbated the adverse effects of nighttime lighting? And will they have served to continue alienating urbanites from the starry night sky, or helped to create a new means of experiencing and interacting with darkness? What sort of medium will the next generation of illumination bring about?

Accepting this new technology uncritically would mean ignoring the lessons we can draw from the cultural history of electric lighting. Further, this next generation of lighting will be layered over the physical and symbolic legacy of the past century of illumination, building on past choices that, although perhaps once contentious, have now faded into normalcy. Through looking back at the history, heritage, and baggage of electric modernism, we are better prepared to look forward.

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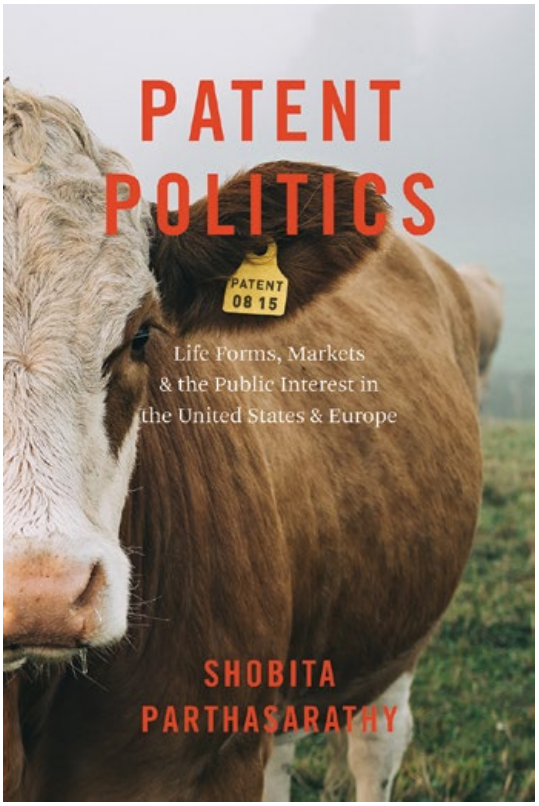
Rights to Life?

REBEKAH SIMON



Patent Politics: Life Forms, Markets, and the Public Interest in the United States and Europe
by Shobita Parthasarathy. Chicago, IL: University of Chicago Press, 2017, 290 pp.

In 1996, the United States Patent and Trademark Office (PTO) awarded patent protection to Myriad Genetics for a gene that it had sequenced, called BRCA1, and a test for diagnosing mutations in the gene that indicated a susceptibility to breast cancer. Myriad, a publicly traded company headquartered in Salt Lake City, wielded its patent's legal authority aggressively, shutting down competitors providing breast cancer susceptibility testing services as well as institutions performing BRCA1 research. The patent was legally justified as a reward for Myriad's technical innovation and contribution to the field of medicine in sequencing the gene. Yet as Shobita Parthasarathy demonstrates in *Patent Politics: Life Forms, Markets, and the Public Interest in the United States and Europe*, the laws protecting the intellectual merit and market value of such innovative technologies are not always easily reconciled with society's moral underpinnings.

In just under 300 pages, Parthasarathy takes readers on a deep dive into the tumultuous evolution of patent systems in the United States and Europe, first by constructing historical frameworks for each and then by applying them to the systems' different reactions to morally ambiguous innovations in biotechnology, such as the patenting of BRCA1. Patent systems were initially designed to incentivize innovation by offering innovators temporary exclusive rights to make and sell their inventions. However, Europe and the United States each introduced qualifications to the idea of an "invention" early on: European systems

expected patentable inventions to preserve or improve society, while the US system merely expected them to be novel (and, ideally, marketable). These differences in the scope of patentable innovation primed the development of a large ideological schism between Europe and the United States regarding how patent law should address the social concerns and implications of new technologies.

Parthasarathy's meticulous documentation of early patent law details the beginning of this rift. Her contrast of Europe's national patent systems of the eighteenth and nineteenth centuries with the fledgling federal PTO in the United States also suggests that this fissure has widened substantially over time. She says that the earliest European patent systems incorporated societal values by promptly adopting practices of *ordre public*, a French construct "prohibiting patents on any technology deemed contrary to public policy or morality," and compulsory licensing, a German mandate that "gave governments the power, under specified circumstances, to step in and force patent holders to allow others to make and sell an invention if the patent holder either refused to do so or set the prices of its invention too high." In comparison, after a Supreme Court ruling regarding the patentability of two water pumps in 1817, the US PTO adopted a much narrower set of moral criteria, in which a patent "could be prohibited because [it] did not have a beneficial use, but rather [was] pernicious, frivolous, or worthless."

Ultimately, the European systems' explicit involvement in the moral considerations underlying patent approval, Parthasarathy argues, primed the European patent to be a powerful instrument of ethics in a rapidly technologizing society. This was especially true following World War II, when national institutions gave way to integrated, cross-border institutions such as the European Patent Office (EPO). Over time, the EPO limited patents on pharmaceutical products (though synthesis processes could be patented), certain foodstuffs, and many genetically engineered plants and animals for a variety of ethical reasons.

In comparison, when the US PTO came face to face with rapid innovation in the early twentieth century, its already narrow moral code slipped into obscurity. Industrialization-era patents in the United States were exclusively "techno-legal" documents that served solely to certify novelty and provide commercialization incentive. Both representatives and users of the US patent system vociferously objected to the adoption of European-style government oversight mechanisms, deeming them threats to future market growth and technological advancement. Parthasarathy extracts two defining concepts of this ideological skirmish from her elegantly paraphrased testimony of a member of the US Patent Law Association to the US Congress in 1914: "rational market participants [do] not suppress their patented inventions," and "industrialists and their legal representatives [are] the appropriate experts because they [bring] experience with the patent system."

Parthasarathy also shows that the European and US patent systems treat stakeholder involvement differently. The European systems' early adoption of nontechnical patent inspectors and later engagement with ethicists and advocacy groups, such as Kein Patent Auf Leben (No Patents on Life), bolstered their credibility as both technical and moral authorities on patentability. Parthasarathy notes that prior to the European Union's (EU) adoption of the Biotech Patent Directive (BPD) in the 1990s, "EU parliamentarians understood patents as having ethical, social, and economic implications and envisioned a patent system that would take responsibility for these issues." Comparatively, the US PTO consistently leveraged its techno-legal definition to marginalize advocacy groups based on their level of experience with the system, to resist consideration of patentability's moral implications, to force the judicial system to evaluate challenges on what Parthasarathy calls "the domain's narrow goal of certifying inventions," and ultimately to forge a precedent for the systematic exclusion of nonmarket value-based criteria from the process of technology evaluation. This perspective persists even today.

Differences in the scope of patentable innovation primed the development of a large ideological schism between Europe and the United States regarding patent law.

One result of these disparate, entrenched objectives of the European and US patent systems was a series of protracted legal battles surrounding the patentability of new biotechnology. Parthasarathy draws on a cleverly curated selection of judicial proceedings, legal testimony, and mass media reports to show how historical precedent restricted challenges to morally ambiguous patents in the United States, while facilitating their success in Europe. One of these battles occurred over human embryonic stem cells (hESCs), a scientifically valuable type of cell that has the potential to develop into any kind of human tissue.

The US PTO granted several patents to the University of Wisconsin for hESCs that its researchers had isolated and maintained. These patents were eventually overturned—but not because of the moral implications

of patenting life. Instead, the legal challenge to the patents centered on other related scientific findings that should be considered "prior art" and thus invalidate the novelty of hESCs. (The patents were later partly reinstated on appeal.) Other winning strategies for challenging biotechnology patents included characterizing life-related technologies as "natural," and therefore not an invention. That the patents inhibited further research and unfairly reallocated federal research dollars toward licensing fees was a secondary argument, since the historical precedent of the PTO effectively neutered its effectiveness.

Conversely, by institutionalizing morality into the patent process from the outset, the EPO positioned itself as both an ethical arbiter over technology disputes and an organization that could include nonlegal expert stakeholders in decision-making. When the EPO awarded a patent for hESCs to the University of Edinburgh, opposition groups immediately argued that "the patent violated both the … *ordre public* clause, and the BPD's explicit language that forbade patents … of human embryos." This opposition grew to include hundreds of private citizens and a rebuke from the European Parliament that the EPO had abdicated its moral responsibilities. Eventually, the EPO's own Opposition Division ruled that patenting hESCs was immoral, and the European Court of Justice invalidated the university's hESC patents. This achievement on the part of those seeking to use patentability to address ethical concerns was not attained painlessly, but as Parthasarathy concludes, "that European patent institutions continued to try to address these issues [of access to technology for the greater public good] marks the real difference between the US and Europe."

Parthasarathy's final discussions regarding recent concerns over the BRCA genes and plant seed patents complete her vivid historical collages of the two patent systems' evolution. As one might now expect, the US Congress's oversight regarding the PTO's decision to award Myriad Genetics the BRCA1 patent was extremely narrow; it was motivated by the market suppression Myriad's monopoly on genetic testing appeared to cause. Similarly, in arguments before the Supreme Court, advocates contesting Myriad's patents averred, in Parthasarathy's words, "that human gene patents violated US patent law's 'product of nature' doctrine," acknowledging that the justices would not adjudicate based on moral violations alone. The Supreme Court agreed, finding that naturally occurring DNA sequences, such as BRCA1, cannot be patented. Such legal acrobatics were less necessary to overturn the patents awarded to Myriad by the EPO. Indeed, the BRCA1 case led to a new EPO practice of incorporating socioeconomic impacts of patents into considerations of *ordre public*, which was a major component of public and parliamentary feedback during the legal battle.

Patent Politics is both a timely and salient contribution to a number of current discussions about the role of government in democratic society, and a prime example of how society can use hindsight to shape future policy. The book offers compelling evidence that citizens expect instruments of policy to extend beyond formal legal obligations, and to incorporate societal morals and values. Yet it also warns those citizens that short-sighted exclusion of the historical forces shaping political discourse will not result in enduring institutional change.

In the United States, both points are relevant to understanding and influencing the politics of health care reform, fossil fuel development, immigration law, and other value-laden issues. In Europe, the European Commission acknowledged morality in law by adopting in 2017 the European Pillar of Social Rights, which strives to encode a number of societal values in a guiding document for policy-making. Parthasarathy's analysis of the patent systems serves as a cogent reminder to policy-makers that many citizens, even in democratic societies, are dissatisfied with the overall structure of decision-making. Similarly, the history of the patent systems strongly parallels public discourse regarding the role of government versus the free market. The US patent system is undoubtedly low on the list of priorities for reform, but Parthasarathy demonstrates that it may in fact be a beautifully self-contained example of how successful reform efforts must be, at least in part, constructed around US institutions' historic obsequiousness to market values.

Finally, *Patent Politics* reflects on the consequences of expanding policy-making institutions to include a more diverse selection of expertise, and shows that both policy-making and technological R&D can benefit from more inclusive tactics. The body of literature in support of scientific codesign and coproduction (in which scientists and other social groups work together to produce new knowledge) is significant, and one could easily marshal Parthasarathy's analysis of life form patents to test the extension of similar concepts—such as the inclusion of nonexpert stakeholders and nonmarket values—to policy-making. This makes *Patent Politics* a formidable contribution both to the science and technology studies literature as well as to the burgeoning field of bioethics. Parthasarathy masterfully juxtaposes complex human morality with the rigid framework of law, and demonstrates that with a little bit of encouragement they can be far more complementary than expected.

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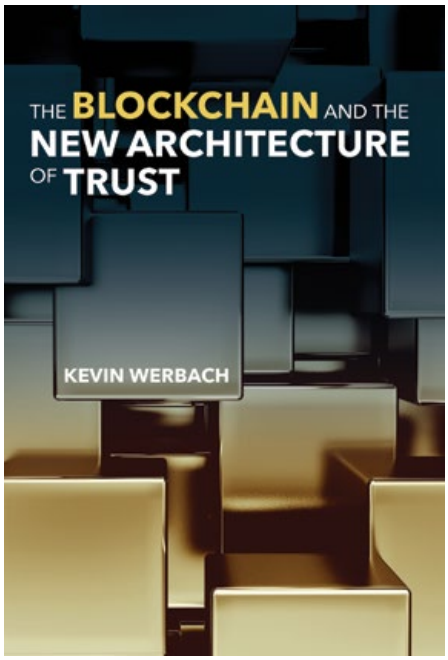
Who Can You Trust?

DRAGAN BOSCOVIC

Kevin Werbach's *The Blockchain and the New Architecture of Trust* offers easy-to-follow explanations of how a technology resting on foundations of mutual mistrust can become trustworthy. If you are interested in gaining a deeper perspective on the blockchain landscape, beyond the hyped claims of techno-utopians or regular reports of cryptocurrency hacking and financial fraud, then this well-researched and well-cited book is for you. It offers an optimistic sense of the possibilities of blockchain technology, supported by governance, regulation, and law, which could have a wide range of important applications.

Werbach is a professor of legal studies and business ethics at the University of Pennsylvania's Wharton School. He is a renowned expert on emerging technology, earning his reputation by using his interdisciplinary research interests to map how business, law, and society are impacted by technologies such as broadband, big data, gamification—and now blockchain. Along with these accomplishments, Werbach 20 years ago helped the US government develop its approach to internet policy as the counsel for new technology policy at the Federal Communications Commission during the Clinton administration.

The Blockchain and the New Architecture of Trust is a balanced book for anyone who wants to sift through the blockchain hype and understand the technology's implications for business and society. Blockchain is essentially a digital public database, or ledger, of transactions that is stored on computers around the world. It is nearly impossible to change or tamper with data in a blockchain, and no single entity controls or owns the blockchain. Although the original blockchain was developed in the late 2000s to track balances for the cryptocurrency Bitcoin, it can be used for many kinds of digital transactions, including verifying contracts, authenticating records, and tracking health records.



The Blockchain and the New Architecture of Trust
by Kevin Werbach. Cambridge, MA: MIT Press, 2018, 344 pp.

The central theme of Werbach's book is how blockchain technology, which relies on building trust in a trustless system, can become broadly accepted as trustworthy—and be used by consumers, businesses, and governments to build real-world applications. Werbach offers his views on what the future might look like for the technology while highlighting the importance of creating legal and regulatory clarity to support innovation and protect consumers. He does an exceptionally good job of explaining how blockchain works, its history, the hype associated with it, and the concerns it has created. The book details concrete examples both from the development of blockchain and the development of the internet, drawing parallels between the two in terms of their relationship to the law.

Werbach offers reasoned explanations as to why blockchain is far more than a slow, immutable database or a difficult-to-understand cryptographic method. Instead, he focuses on the benefits of the supreme efficiency of synchronization in a distributed system such as blockchain. He argues that although blockchain is inefficient and slow in processing and recording individual transactions, it is far more efficient in establishing the global state of the system. This is important because when all the globally distributed nodes in the blockchain ledger work with the same level of information and avoid making irrelevant or wrong decisions, consensus builds up in blockchain's trustless operations.

The book, perhaps uniquely among the many volumes devoted to Bitcoin and the blockchain, explains that law and regulation must play a central role in reinforcing the built-in trust of decentralized digital ledgers. Werbach postulates that blockchain isn't an alternative to trust; instead, it helps remove dependencies on intermediate entities in complex transactional workflows. Contrary to the mysterious Bitcoin developer Satoshi Nakamoto's conclusion in his 2008 white paper that introduced the blockchain, in which he claimed that "We have proposed a system for electronic transactions without relying on trust," the complete circumvention of trust is simply not possible. Trust is essential to how human society functions, and it goes beyond the formal security of consensus on a distributed ledger.

To that end, Werbach argues that society needs a better understanding of what kinds of problems blockchain is capable of addressing, based on the kinds of trust needed for particular classes of applications. He puts forward a thought-provoking thesis that the legal system will be the primary force that determines whether a given blockchain ecosystem succeeds. That should not be surprising, bearing in mind that law, regulation, and governance are mechanisms of trust in conventional socioeconomic structures and, as such, will be used to promote trust in blockchain-based solutions as well. But this has not been part of the hype around

blockchain, whose advocates claim that the technology can bypass traditional institutions entirely.

Despite the fact that the book was published in November 2018, in the midst of the most recent cryptocurrency market crash, it portrays the blockchain technology that underpins cryptocurrency as the next great digital platform, whose future—not necessarily linked to crypto asset boom and bust cycles—is incredibly bright. Although cryptocurrencies are prone to price volatility, Werbach doesn't question the sustainability of the whole blockchain concept for applications of trust. This can be seen in cases in which the cost of trust is a problem (typically proportional to the number of trust layers or intermediaries in a given workflow; think of all the entities involved in a simple credit card transaction, for example), or where there is a "trust gap" among coordinating entities. The first case applies to most cryptocurrency or digital asset use cases, while the second generally represents enterprise applications, such as corporate supply chains.

Werbach identifies three main blockchain applications. The first uses cryptocurrency to create financial inclusion opportunities for the so-called unbanked by removing inefficiencies related to financial transactions. The second tracks assets using the distributed ledger technology that blockchain enables. This is particularly important in financial services and in supply chains, where there are multitrillion-dollar problems associated with a lack of unification across the system. The third involves regulated asset trading through security token offerings and crypto-derivatives; these are basically blockchain-based coins or tokens that are sold to investors to raise money for a project. (Most of these endeavors, it should be noted, fail within the first few months; the system is plagued with scams and securities law violations—hence the need for *regulated* asset trading.) The prospect of a secure, programmable, digital token that represents assets or intangibles is a Wall Street dream, and financial communities around the world are racing to turn that dream into a reality.

The book identifies four different trust architectures. The first is peer-to-peer trust, which typically comes about when individuals learn to trust each other based on morals and reputational systems. The second is leviathan trust (so named after the English philosopher Thomas Hobbes's conception of the state), which corresponds to an institutional trust that allows distrustful parties to enter into agreement because they trust that a government system will help resolve disputes. The third is intermediary trust, in which parties do not need to trust each other if they trust the intermediary; a good example is the credit card system, which allows buyers and sellers to engage in commerce. The fourth—the "new architecture of trust" of the book's title—is distributed trust. This refers to the users' trust in the particular decentralized system that is blockchain, without requiring trust in any of the system's individual components.

Blockchain solutions don't eliminate the need to continue to trust human institutions. There will always be a need for institutional sources of trust that can't simply be replaced by technology alone. Any blockchain system will have to coexist with other, more conventional systems. Humans need to stay in charge, and there is always a need for governance and oversight outside the system. As long as "hard forks" are a possibility—that's when the people in charge of a blockchain step outside the system to change it—people will need to be in charge.

What blockchain does, and where its value lies, is to shift some of the trust in people and institutions to trust in technology. Blockchain users trust the cryptography, the protocols, the software, the computers, and the network, but this trust must be embedded in larger governance systems. Blockchain-based contracts, for example, need viable dispute resolution mechanisms, which will be a combination of traditional legal recourse and arbitration, on one hand, and novel decentralized approaches on the other.

Currently, when user trust in blockchain turns out to be misplaced, there is no recourse. If a Bitcoin exchange gets hacked, or you forget your log-in credentials, you lose your money. If there's a bug in the code of your smart contract, the contract could be invalid. In many ways, trusting technology is harder than trusting people. Would you rather trust a human legal system or some computer code you don't have the expertise to audit? On the organizational side, the biggest challenge in most business and financial service implementations of blockchain technology is getting the participants to cooperate. Just because blockchain technically offers secure data sharing without giving up control doesn't mean companies will feel comfortable ceding power to blockchain-based ventures involving their competitors.

Werbach offers an insightful explanation of blockchain's relationship to internet architecture. Many factors, mostly having to do with security, have led to a centralization of some of the internet's key architecture. Blockchain could function as a new layer in the internet's structure, one that can strengthen such functions as identification, authentication, attestation, and property rights. In other words, blockchain could not only remove some of the reasons for strong centralization, but also create a favorable climate for decentralized applications—and presumably for the innovation and experimentation that characterized the early internet.

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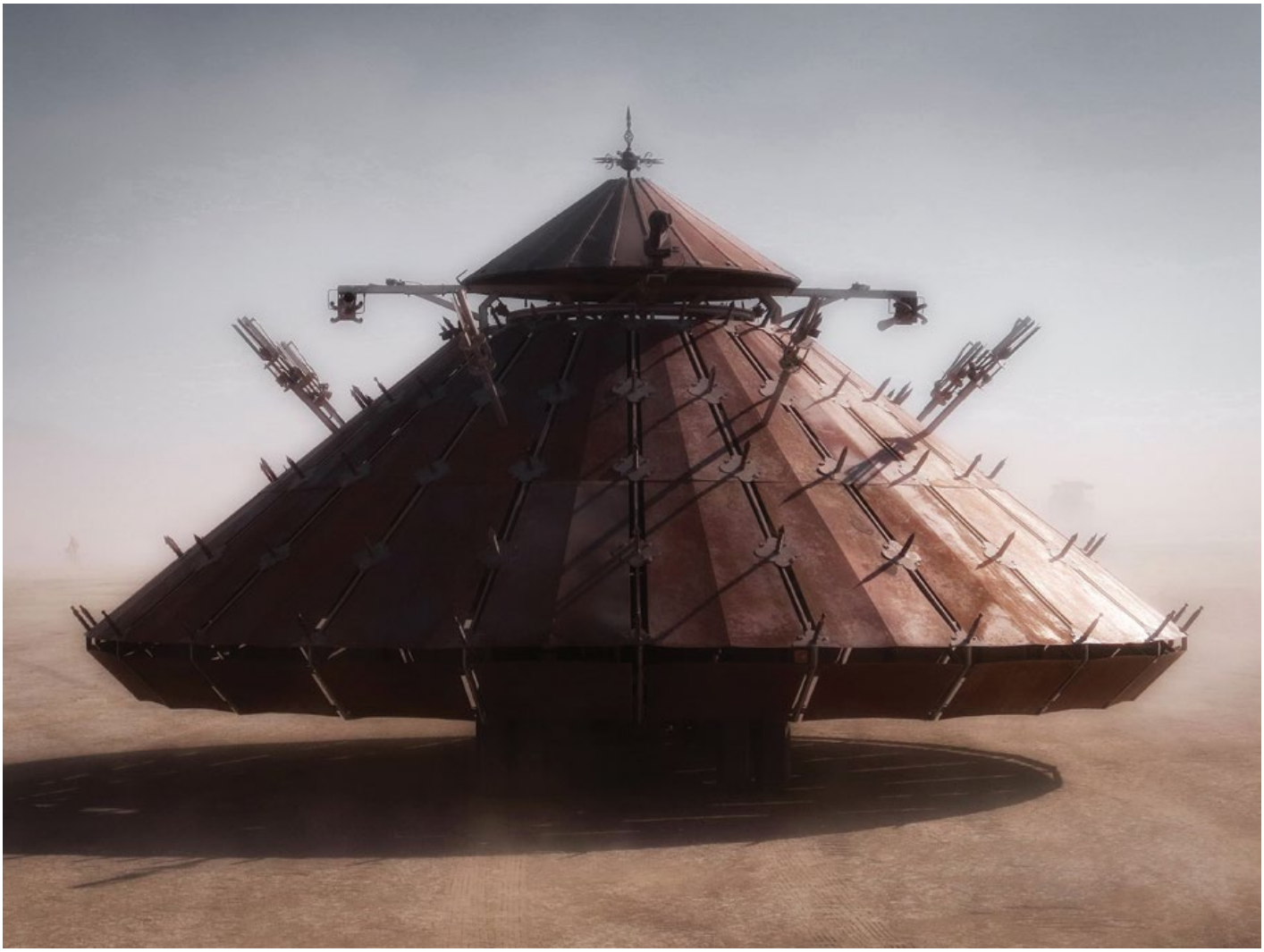

Image courtesy of Walter Productions

Mona Lisa

The 8th Annual Emerge Festival at Arizona State University

Emerge explores the future in evocative ways, exploring the latest inventions from ASU and beyond and asking how we might shape and adapt them in surprising ways. By bringing together artists, scientists, humanists, designers, performers, and scholars, Emerge draws on ASU's diverse ecology of world-renowned researchers and its culture of interdisciplinary exchange to create vibrant portraits of alternative futures.

The 8th annual Emerge festival in March 2019 celebrates human inventiveness by marking the 500th anniversary of the death of Leonardo da Vinci. Depicted here is the aptly named immersive installation *Mona Lisa*, developed by Walter Productions. Inspired by Leonardo da Vinci's sixteenth-century tank design. Its frightening exterior contrasts with its inviting and intimate interior.