Vol. 50, No. 1 January 2021

PHYSICS & SOCIETY

A Publication of The Forum on Physics and Society A Forum of The American Physical Society

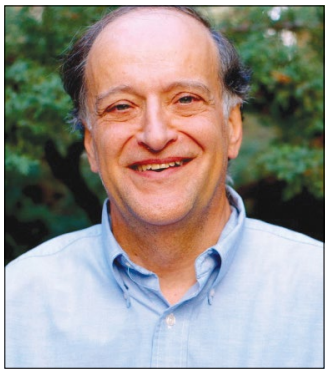
From the Editor

I am very pleased to announce in the "News" section this issue the winners of the two APS Forum sponsored awards. Congratulations to Robert Semper (Burton Award winner) and to Steve Fetter (Szilard award). You can read the citations below.

We have also the election results for Forum officers. We had an excellent slate of candidates. The only thing not to like about the election is the low participation, about 15% of the Forum membership only. The officers of the Forum play a crucial role in its activities and an important one in the APS in general. Let us do better next time.

I am happy to say that the COVID-induced drought in submissions to this newsletter seems to be easing out. I want to highlight the fascinating article by our 2020 Szilard award winner, France Córdova, on her extremely broad experiences in the world of science policy. We have also two more articles, including a timely one by one of our own Board of Editors member and our usual book reviews.

The last few weeks have revealed what has to be the greatest triumph for science for many years: the development of safe and effective vaccines for the Covid-19 virus in the record time of less than a year. This is a great achievement on the part of the scientists that did the work, and also on the part of the politicians that backed them and their companies financially. It is great to see science and society at large working together so well. Praise is due to scientists (and I hope soon to be Nobel laureates) Ugur Sahin and Özlem Türeci for developing the mRNA method, and to Boris Johnson for helping the United Kingdom be the first country to administer the vaccine.



Oriol T. Valls, the current P&S newsletter editor, is a Condensed Matter theorist.

Once again, this newsletter is dependent on contributions from its readers and forum members. Articles on any "physics and society" related topics, broadly understood, are welcome and I have no restriction on points of view. Articles and suggestions for articles should be sent to me, and also letters to the editor. Book reviews should go to the reviews editor directly (ahobson@uark.edu). Content is not peer reviewed and opinions given are the author's only, not necessarily mine, nor the Forum's or, *a fortiori*, not the APS's either.

Oriol T. Valls
University of Minnesota
otvalls@umn.edu

IN THIS ISSUE

EDITOR'S COMMENTS

FORUM NEWS

2 Announcement: From the Media Editor

2 Forum–sponsored 2021 Award winners

3 FPS Sessions for the 2021 March and April Meetings

ARTICLES

4 The Importance of Science Policy
France Córdova

8 Powerlines and America's Continuing Energy War
Rik Gran

13 Were the Polls Wrong?
Richard Wiener

REVIEWS

15 The Precipice: Existential Risk and the Future of Humanity
by Toby Ord, Leonard Finegold

16 Losing Earth: A Recent History
by Nathaniel Rich, Quinn Campagna

Announcement: From the Media Editor

2020 was a challenging year for all of us as we navigated communications with friends, colleagues and our communities through a global pandemic. Activities such as "Zoom birthday parties" or "virtual conferences" have forced many of us to learn new technologies and be creative when it comes to staying in touch.

As our newsletter continues to provide an outlet for this community, we want to make sure we're reaching you all where you are and fostering that sense of community and interaction. Our media presence is one way to do so and we wanted to encourage you to check out our blog at https://physicsandsocietyforum.wordpress.com that houses all of our published newsletter articles and allows viewers to leave comments or share those individual articles on other platforms. We also have a Facebook page www.facebook.com/APSPhysicsAndSociety where we highlight articles and would love to expand to highlight other events and stories that you'd like to share with us and each other

If you have other ideas on how we can continue to expand our media presence, please contact our media editor directly at tabithacolter@gmail.com

Tabitha Colter

Forum–sponsored 2021 Award winners

JOSEPH A. BURTON FORUM AWARD

Robert Semper
Exploratorium

Citation: "For extraordinary accomplishments exposing educators, policymakers, and the general public to the wonder and joy of scientific exploration, especially in physics, through the development of Exploratorium exhibits and educational resources, and assisting in the creation of Exploratorium spinoffs in many communities."

LEO SZILARD LECTURESHIP AWARD

Steve Fetter
University of Maryland, College Park

Citation: "For seminal contributions to two US administrations' efforts to minimize the threat of nuclear war, for helping to establish nuclear archeology as a viable and effective method for supporting arms control and countering proliferation, and for contributing expert analysis leading to the UN General Assembly's adoption of the 1996 Comprehensive Nuclear Test-Ban Treaty."

Physics and Society is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. ***Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum. Articles are not peer reviewed.*** Contributed articles (up to 2500 words), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.

Editor: Oriol T. Valls, ***otvalls@umn.edu***. **Assistant Editor:** Laura Berzak Hopkins, ***lfberzak@gmail.com***. **Reviews Editor:** Art Hobson, ***ahobson@uark.edu***. **Media Editor:** Tabitha Colter, tabithacolter@gmail.com. **Editorial Board:** Maury Goodman, ***maury.goodman@anl.gov***; Richard Wiener, ***rwiener@rescorp.org,*** Jeremiah Williams, ***jwilliams@wittenberg.edu***. **Layout at APS:** Leanne Poteet, ***poteet@aps.org***. **Website for APS:** ***webmaster@aps.org***.

Physics and Society **can be found on the web at** www.aps.org/units/fps**.**

FPS Sessions for the 2021 March and April Meetings

MARCH MEETING 2021

AI and Humanity: Governance, Design, and Ethics

Chair: Savannah Thais, Princeton University
An Ecological Approach to Data Governance, Design and Ethics
Jasmine McNealy, University of Florida
AI and its Computing Landscapes: Water Data, Climate Control, and Agricultural Technology
Theodora Dryer, New York University
Measuring Fairness in Machine Learning Systems
Melissa Hall, Facebook
A Physics Perspective
Savannah Thais, Princeton University
Panel Discussion

Communicating Science to the Public

Chair: Richard Wiener, Research Corporation
Science in Popular Culture
Ann Merchant, The National Academy of Sciences
The Role of News Journalism
Dennis Overbye, The New York Times
Panel Discussion on Opportunities and Challenges in Communicating Science to the Public
Ira Flatow (Science Friday), Dennis Overbye, Ann Merchant

Science Diplomacy (joint with the Forum on International Physics)

Leadership in Fundamental Physics Research in South America
Nathan Berkovits, Universidade Estadual Paulista
Advancement of Physics and Science in Developing Countries
Fernando Quevedo, University of Cambridge
Allegations of Scientific Espionage
Xiaoxiang Xi, Temple University (2020 Sakharov Prize winner)
Peace Engineering and Engineers without Borders
Bernard Amadei, University of Colorado
LAUNCH: Entrepreneurship for Developing Countries
Todd Khorzein, Second Muse

ELECTION RESULTS, FORUM OFFICERS

The following people have been elected:

Vice-Chair:
Frederick Lamb
Member-at-Large (two elected):
Jennifer Dailey
Tara Drodzenko

Also bylaws changes were approved.

APRIL MEETING 2021

Race, Colonialism, Nuclear Weapons, and Their Testing

Chair: Cherrill Spencer, SLAC National Accelerator Laboratory (retired)
The Intersection of Race and Nuclear Weapons
Vincent Intondi, Montgomery College

Radiation Measurements in the Marshall Islands, Emlyn Hughes, Columbia University

75 Years and Waiting: the Downwinders Perspective of the Trinity Test
Tina Cordova, Tularosa Basin Downwinders Consortium

The Changing Nuclear World Order

Chair: Stewart Prager, Princeton University
Reducing Nuclear Weapons and the Risk of Nuclear War (LEO SZILARD AWARD LECTURE)
Steven Fetter, University of Maryland, College Park
Nuclear Weapons and Missile Defense
Fred Lamb, University of Illinois
The Emerging Technologies Arms Race, Nuclear Weapons, and Global Security
Sebastien Philippe, Princeton University

Awards Session (Jams Burton Forum Award Talks)

Chair: Juliette Mammel, University of Manitoba
Physics, Truth, and the Crisis of Science Denial
Adam Frank, University of Rochester
The Exploratorium at 50: Perspectives on the Development of a Public Science Learning Laboratory
Rob Semper, The Exploratorium

The Future of Earth

Chair: Joel Primack, The University of California at Santa Cruz
The World in 2050 – and Beyond
Martin Rees, Cambridge University
The Future of Life
Anthony Aguirre, The University of California at Santa Cruz
Needed Now: A Vision for Earth on Cosmic Time
Sandra Faber, The University of California at Santa Cruz

Ethics in Physics & Science: Remembering John Ahearne *(Carryover from 2020)*

Chair: Beverly Hartline, Montana Technological University
Ethics in policy advice risk assessment, and national security
Micah Lowenthal, National Academy of Sciences
The survival imperative: critical components of the ethical education of scientists and engineers
Stephanie Bird, Massachusetts Institute of Technology (retired)
Creation, Charge, and Early Accomplishments of the APS Ethics Committee
Michael Marder, University of Texas at Austin

The Importance of Science Policy

France Córdova, former NSF Director, Francecordova@icloud.com

This article derives from Dr Córdova's Luskin Lecture at UCLA in November of 2020.

Science is vital to our daily lives – to our economy, to our health, to our security and, importantly, to our well being – our sense of place in the universe. I believe that good science is enabled by good science policy.

In my travels to telescopes all over the planet, I have marveled at Nene birds in Hawaii, kangaroos in Australia, and springbok in South Africa. Venturing less far, that is, to the corridors of power in these United States, I have met prides of lions and streaks of tigers, and – fortunately -- helpful giants.

Students often say to me: I want to make an impact on society, address inequities, halt the bad stuff I see happening. How can I be an agent of change? They sense that public policy is a route to change.

I tell them to keep in mind the words of the author James Baldwin: "Not everything that is faced can be changed, but nothing can be changed until it is faced."

My world of the last three decades has been the world of science policy. I have been in leadership positions at several universities, including two in the University of California system, and done government service in five administrations. I want to share a few examples of shaping and changing science policy, what motivated this, and its impact, which can go far beyond science. I will outline present challenges that are propelled by scientific discoveries and technological advances, and give my own insights into effectively shaping policy.

FIRST, HOW DID I GET INTO SCIENCE POLICY WORK?

It was the early 1990s, and I was engaged as the head of the department of Astronomy & Astrophysics at Penn State University. I had a supportive husband and two small children. We were happy in Happy Valley.

One day I got a call from the Chair of a national committee of which I was a member; he said he was calling on behalf of the head of NASA to ask me if I would be interested in interviewing for the position of NASA's Chief Scientist. Well, I wasn't at all sure about my interest in the job, but I was interested in having dinner with the head of NASA! Over dinner, I found that we had lots of resonances about what changes needed to be made at NASA. The invitation to join the agency came shortly after that dinner.

Yet I was confounded by this invitation. I had spent so long becoming a scientist, a researcher, why would I want to leave that and immerse myself in the world of policy, and the turbulent environment of Washington DC? I didn't even know what policy meant; it wasn't the same as doing "real" science, I told myself.

I consulted fellow scientists, fellow heads of astronomy and physics departments around the country. All encouraged me not to abandon my current research path. Well, almost all. The head of the department of history at Penn State was a good friend, and she saw the opportunity to speak on a larger, national stage about an issue I consistently addressed on my small university stage: the importance of attracting and retaining women in science. And my closest and best adviser – my mother – agreed.

The deal was settled at the Cheesecake Factory in DC, when I took my spouse and young children to visit with NASA Administrator Dan Goldin and his wife Judy. To this day my children, now grown with families of their own, remember chocolate cheesecake for breakfast.

I became the first woman, and youngest person, to serve as NASA's Chief Scientist. I was about to learn why science policy-making is important to health, the economy, and national security – in short, the improvement of our daily lives.

FIRST STOP, NASA.

For me, one of the exciting things about joining NASA was Administrator Goldin's desire that science be the driver for space missions. I chaired a group of NASA leaders who were charged with determining the scientific capabilities of the International Space Station, which had just been approved by Congress, with the narrowest of margins, and which was in its earliest stages of build. One of the arguments for the ISS was that it would welcome and assist novel scientific experiments that would benefit from the microgravity environment. Today the Space Station has carried many notable scientific experiments, among them the Alpha Magnetic Spectrometer, designed by Nobel Prize winner Sam Ting to look for antimatter and signs of dark matter from the detection of cosmic rays. Today several hundred scientific publications evidence the benefits of the ISS for a number of areas of scientific inquiry, from remote sensing of Earth to studies of loss of bone mass and its treatment to tissue engineering.

To further the NASA Administrator's desire to address profound scientific challenges, I brought to NASA Headquarters scientists with big visions. Carl Sagan was one; Roger Penrose another. Their ideas – articulated in a series of visits and public lectures -- pushed the limits of knowledge and were inspirational. This led to NASA encouraging the new field of

astrobiology. The agency defined a more vigorous program to search for life beyond Earth, to identify and eventually genetically sequence extreme forms of life on our own planet, to support the identification of exoplanets, especially those in the habitable zone, and to develop the technology to identify signs of life on another planet. A number of programs and missions came from this early investment, among them the Astrobiology Institute at NASA Ames, and the satellites Kepler and TESS to look for evidence of exoplanets. Importantly, astrobiology was finally a standalone discipline – or should I say 'interdiscipline' -- combining geology, paleontology, astronomy, biology, geology, oceanography, thermodynamics, chemistry, and planetary science.

Together with colleagues at other agencies I tackled other important science policies through the National Science and Technology Council, the inter-agency policy arm of the White House's Office of Science and Technology Policy. One was formulating a federal definition of research misconduct. The various science agencies had very different definitions of research misconduct and this was challenging for scientists, who had to navigate an uneven road of research integrity – accusations of misconduct were flying at our nation's research institutes and without a good framework there weren't good solutions. We wrangled with words as if they were bucking broncos and it took three years to get all the science agencies on the same page. The federal definition of research misconduct that resulted from our initial efforts in the early 1990s has endured to this day. From this experience I learned that patience is a tool, and uncompromising clarity a virtue. I also learned to chair a diverse group of people, representing agencies with different missions.

NEXT STOP, THE UNIVERSITY OF CALIFORNIA

With this introduction to the world of science policy, I left NASA to join UC Santa Barbara as Vice-Chancellor for Research. I was committed to encouraging faculty to work together on novel research projects across disciplines. That's partly a reflection of my own background in the humanities, social sciences, and physical sciences. I wanted to see more of the innovation that comes from working on the boundaries between disciplines.

I requested and received a "dowry" from Chancellor Henry Yang to start an internal funding program called Research Across Disciplines, or RAD. You have to understand: at the time (1996) the word interdisciplinary was not common in the vernacular. And it was hard for researchers to get funded by the federal government for untried, high-risk concepts. The program turned out to be extremely successful. Some very creative work was done. Most of the projects, funded for small amounts like $50 K, were able to demonstrate sufficient proof of concept that they went on to be funded by federal agencies and foundations for millions of dollars. I didn't know it at the time, but it was a step towards my eventual position as director of the National Science Foundation, where investment in "high-risk, high-reward" projects produced groundbreaking scientific discoveries, and "interdisciplinary" would morph into "convergence." More about that later…

I left UCSB to become Chancellor at UC Riverside. At first I thought that the main goal should be to get the campus into the AAU because, well, that's what all institutions wanted. But as I got to know the "Inland Empire" of Riverside-San Bernardino better, it became clear that what this region of 4 million people needed was a public medical school. The region's lack of general medical practitioners was great. I learned that most physicians live close to the coasts of our country. I also learned that the world of medicine was not very diverse; the ethnic diversity of the UCR area was a resource that could be drawn upon for youths interested in medicine.

I knew it would be a hard road to travel. After all, UC already had five prominent medical schools and the last one was started 42 years earlier. So, who needs another medical school in California? I feared that the deans of the other schools might see UCR's efforts as taking potential donor funds or State appropriations from them. But my fears were groundless. The need-based case for a medical school in the underserved Riverside-San Bernardino region was so strong that all of the UC deans were supportive (especially Gerry Levy, Dean of UCLA's School of Medicine), as were the UC Regents. It was, for me, a lesson in making policy: Identify the real needs of a community. Don't assume all the lions and tigers are unfriendly. Ask the giants to be your friends. Know where it is you want to go. Encourage teamwork and community support to get there.

MOST RECENT STOP, NSF

My first introduction to NSF was as Principal Investigator for an NSF ADVANCE grant when I was president of Purdue University. ADVANCE was, and still is, a program to encourage and support the upward mobility of women faculty at universities. Its goal was institutional change. Purdue's focus was to enrich the pool of minority women faculty and, as president, I was in a position to make institutional change happen. My second introduction to NSF was my nomination by President George W. Bush to the National Science Board. The NSB is the policy arm of NSF. It shares governance of the agency with NSF's Director. Five years later, President Barack Obama nominated me as Director of NSF. The U.S. Senate confirmed both appointments, to the Board and as Director. … I was about to get to know the U.S. Senate much better…

I had lofty expectations for the job of NSF Director. After all, the agency had its genesis in what is still the most referenced science policy document in our nation's history, called "Science – the Endless Frontier." We celebrate this year the 75th anniversary of its publication. Its author was Vannevar Bush, head of the Office of Scientific Research and Development during WWII and adviser to the President.

Bush was a powerful advocate for basic research and laid out the arguments for a national science agency. Five years later, Congress authorized the establishment of NSF.

During my first week on the job, I received a letter from the chairman of the agency's congressional authorization committee, called the House Science, Space and Technology Committee (HSST). This letter from Congress rebuked the agency for funding 20 projects that were deemed not in the national interest. The Chairman wanted the agency to deliver the proposals for these projects to his committee for its inspection. We, in turn, invited his congressional staff to NSF to review the proposals where we could be present. In time, more projects made the list; it was not exactly the kind of list a young scholar aspired to make. Vivid articles appeared in the press, some sensationalizing these and other projects that appeared in Congressional "wastebooks," and others defending NSF's vaunted merit review process, which had approved these projects. Soon I was testifying on this subject before Congress, vowing to lead an agency that would hold itself accountable for the projects it approved, promising transparent titles of proposals, and abstracts that were simpler to read. I was repeatedly asked to verify that all funded proposals were "in the national interest." I responded: "Isn't our agency's mission – to promote the progress of science – in the national interest, and as such, wouldn't every approved proposal be in the national interest?

And so it went for over a year; more Congressional wastebooks from both House and Senate collected on my desk. We defended each criticized proposal in writing in on our website. We visited with the Congressional authors of the wastebooks . And we carefully reviewed all proposal titles and abstracts to ensure they clearly articulated the public benefit of the research. Yet the tide seemed to be against us.

HOW DID WE GET OUT OF THIS JAM?

It's no fun to be on the defense continually. We realized that we needed a good offense. Within six months to a year we employed three offensive strategies:

We tamed the 'lions' by accompanying them on trips to sites where NSF science is done, like the South Pole in Antarctica and Greenland's Summit. Getting to know and talk with people who think differently is best done on neutral ground and with plenty of time for fellowship. And the congressional representatives were able to see astrophysics, geologic and environmental research in action and talk with young scientists on their own research ground.

The agency worked hand-in-hand with its "giants", the distinguished members of the National Science Board. They had been appointed across administrations and had connections throughout the broader community and Congress. They supported the actions of the agency to meet its challenges and promote its mission with public statements and visits to Congress.

THE AGENCY CAME UP WITH TEN BIG IDEAS FOR FUTURE INVESTMENT.

This was a new strategy for NSF, which before this had welcomed all proposals, reviewed them, and selected the best through peer review. The Ten Big Ideas pointed to a future promising scientific and technology discoveries and innovation. It was a strategy that worked beyond what our wildest imagination had envisioned. Other nations (including China and European nations) wanted to participate in the Big Ideas, and some sought our advice on promoting big ideas of their own. The new administration resonated with several of our Big Ideas (quantum, A.I., big data), making them its "industries of the future." The national academies and leading universities, which had promoted a convergent approach in science, extolled our Convergence Big Idea. Scientists and engineers met opening more opportunity for mid-scale research instrumentation with enthusiasm and scores of proposals totaling billions of dollars. Our Multi-Messenger Astrophysics Big Idea was reinforced with several breakthroughs, including the first detection of gravitational waves on Earth and Nobel prizes for those who made it happen. These discoveries would have happened anyway, but the Big Ideas gave them an organizing principle and a framework for future investment. Congress was enthusiastic about funding the Big Ideas, and our budget increased over the next few years.

The tide turned. The wastebooks stopped publication. The energy was now on the future. Everyone was asking: what investments need to be made to continue to position the U.S. as a global leader? And NSF was ready to help lead the way.

MANY OTHER WAR STORIES IN THE POLICY ZONE

I will recount just one more. It's an important one that runs like a vein through my life.

There is an old Chinese saying: women hold up half the sky. I realized, early on in my career as a scientist and administrator that science has failed to hold up its share of the sky because it is lacking vital participants: women and minorities. At NSF we wanted to combat this exclusion through policy and programs. Programs are for the here and now – they get the ball rolling. Policy is for longer – it keeps the ball rolling.

Fairly soon after I joined NSF we started the INCLUDES program to reach the people science often ignores – those living in underserved regions of the country; women; minorities of all kinds. We invited proposals for pilot projects around the country, and funded 70 of them immediately. The program was extremely successful, with lots of innovation in broadening participation in STEM. We brought the leaders of the projects together to share their ideas and their successes, both in person and virtually. We funded a backbone organization to link all the individual programs, to give the effort the scale it had lacked. Before I left the agency several other science

agencies had joined the INCLUDES movement, NASA being prominent among them. INCLUDES was actually the first of our Ten Big Ideas. On stage, when I've been asked which was my favorite of the Ten, I would say INCLUDES; if you encourage and fund a wide diversity of talent, all other Big Ideas will follow.

Reaching out to people who knew nothing of science and welcomed outreach was important, and INCLUDES and other NSF Broadening Participation programs endure and are successful. Yet we felt at NSF that there was much more to do. We realized that there were other people, many others who were already doing science and being turned away because of bias, explicit and implicit. The National Academies wanted to study this issue, focusing on the harassment of women in science, and NSF funded them. Their eventual report of 2018 was to become by far the most downloaded report in Academy history.

Again, it was the media that provoked us to do more at the agency. Stories of abuse of women in science were prevalent, and it was shocking news. In early 2016 both I, as NSF Director, and Charlie Bolden, as NASA Administrator, sent letters to the university community reminding them that harassment was not to be tolerated and the universities could lose all their funding if they did not get on top of this issue.

But the media reports of harassment continued with a deafening roar. It turned out that in this case the lions and tigers were sitting and working among us. Science was being harmed by the misconduct of a few – scientists! When you lose a young woman to science because of abuse, particularly from a person respected in science, you have lost the potential of science itself. Imagine if any of our current female Nobel Prize winners had given up because of harassment from those in their own workspace. Imagine the loss to discovery.

We realized at NSF that we had to do something more than write letters to university presidents and vice-presidents. We needed to find a way to fight what was a cultural and social issue through policy. Instituting new policy, we discovered (alas), was harder than instituting new programs.

We revised and published codes of conduct for all of our field sites. Then, through careful study and teamwork – gathering the forces of our legal department, public affairs office, office of diversity and inclusion, and led by the office of the director – we devised a careful-worded policy change to the terms and conditions of our awards that would require universities to notify us of potential harassers on campus if there was any administrative action against them. The agency could then decide if the university's NSF grant could be retained under different research leadership, or not. It was a big change for the agency and took months to get through various hurdles, including responding to hundreds of queries by universities. Yet already it is having an effect and other agencies are starting to adopt a similar policy. In truth, it was a change in policy that moved toward changing culture.

As University of Maine scientist Jacquelyn Gill said in Gizmodo, … "It's been too easy to dismiss these incidents as isolated or all in women's heads. To have big sweeping policies at the most respected institutions really legitimizes what we've been saying for a long time."

MY REFLECTIONS

Those are my reflections on the rough-and-tumble world of science policy. Every policy – including policies that shape the culture of science – has the potential to have far-reaching consequences.

Today we are faced with many challenges, and science and science policy have important roles to play. One of the trickiest challenges is that the well-intentioned goals of some people and organizations conflict with the well-intentioned goals of others: an example is the current launch of tens of thousands of communication satellites, designed to give internet access to people in rural areas. Yet these spacecraft interfere with the observations of telescopes designed to look deep into the sky to understand the origins of stars and galaxies, dark matter and dark energy, and you and me.

There are arguments over the uses of CRISPR-Cas9 technology, the good and bad potential uses of artificial intelligence, and the degradation of the environment vs. regulation of industry. (One of NSF's Ten Big Ideas addresses the need to understand and mitigate the rapid and consequential changes happening in the Arctic). There are strong feelings when it comes to the efficacy of vaccines; those will play out on a national stage soon as we struggle to recover from the dreadful epoch of COVID-19. It will take backbones of titanium, a capacity for listening and compromise – and a diversity of thinking -- to tackle the policies that will define the frameworks for the use of these new technologies.

HERE ARE MY INSIGHTS INTO SHAPING GOOD POLICY.

These apply to all policy, not only science policy.

1. Strive to make things better through policy. Policies are the procedures, processes, programs and rules that represent an organization's principles and further its mission and goals. Your policies should reflect your principles, and accelerate your mission. Good policy documents – from our Constitution to Vannevar Bush's report "Science—the Endless Frontier" – endure.

2. Give-and-take. Make the shaping of policy a win-win for all the participants. We need to get back to the fine art of debate. We have to be able to listen to objections about draft policies, and fix them. We need to have a spirit of compromise. Our country was reared from its inception on thoughtful policy,

debated for years before its Constitution was finalized and ratified. The Bill of Rights (which comprise the first ten amendments) was not an afterthought, but a deliberate action to unite the 13 States in support of the Constitution.

3. Work towards the ideal, but be willing to mend policy when the evidence calls for it. Benjamin Franklin sat for years with delegates from 13 States to shape our Constitution. In 1787 he said: "I confess that there are several parts of this Constitution which I do not at present approve, but I am not sure I shall never approve them. For having lived long, I have experienced many instances of being obliged by better information, or fuller consideration, to change opinions even on important subjects, which I once thought right, but found to be otherwise." Ah, you think, he's talking about evidenced-based decision making! Makes sense – we all know Ben as ever the inventor and experimenter.

4. When you are a policy maker, trust your instincts. They will carry you far toward making good policy. At the very least, don't be tempted into approving something that doesn't sit well with your experience and your principles.

5. A policy for all must reflect the voices of all. Diversity of thought makes better policy. Embrace inclusion when formulating policy. Realize that this will take more time, but the outcome will endure longer.

6. Appreciate that the budget is your strategic plan. If your big ideas are not in the budget, they are only ideas, and they probably won't happen.

7. What's in your toolbox? Have you ever had a repairman come to your house and, in the middle of a mess, say that he forgot an important tool and has to leave to get it? Don't be that person. I've mentioned the importance of patience as a tool, and having both a strong defense and a strategic offense. I've mentioned the need for friends, including some giants as part of your team.

That's it: my take on shaping policy and my experience in the world of science policy. It's a long way from the Cheesecake Factory where I had my first bite at policy. I had crossed the great river that would separate scientific research from science policy when I went from being a research scientist to being a policy wonk. I learned to build bridges to connect them. And I have had a great time!

Powerlines and America's Continuing Energy War

Rik Gran, University of Minnesota, Duluth rgran@d.umn.edu

Workers with two electric utility companies energized high voltage direct current (HVDC) power lines, one in 1977 and the next in 1978. This article is about the second one, called the "CU" power line [1]. Both brought energy from new coal power plants in rural North Dakota to the urban and industrial centers of Duluth and Minneapolis-St. Paul (MSP) respectively.

The 1981 book "Powerline: the First Battle of America's Energy War" [2] documented the CU line approval process and the people involved using a mix of reportage, recording transcripts, documents, and interviews. It was written by two professors at Carleton College. The first, Barry "Mike" Casper, was a founder of the APS Forum on Physics and Society [3]. His coauthor, Paul D. Wellstone, was a community activist then later U.S. senator. This article connects the original story of an urban/rural divide to changes in technology and society.

Planning the route for the CU power line through farmland west of Minneapolis erupted in protest. Tense confrontations at county hearings, marches, civil disobedience, and destruction of property began in 1974 and continued into the early 1980's. There are parallels to today's battles over how our energy and economic futures could evolve in the face of climate change.

When energy from distant resources is transported to urban centers via pipelines, rail, and HVDC transmission lines, residents in between do not directly benefit from the activity at either end. The transmission of energy is, at best, an external imposition on the landscape. At worst it is seen as indication their community and livelihood are undervalued, or even under existential threat. Despite a process involving hearings and public input, the decisions had already been made about the need for the power line. Increased energy production from domestic coal was a federal priority [5] as the demand for oil passed domestic supply around 1969 and lead to the oil crisis of 1973. Initial regulatory and financing support for the CU project was easily obtained. Much of the route was subject to easements and eminent domain law, not negotiation with local communities and landowners.

Yet the story in "Powerline" is about a changing regu-

latory landscape. Contemporary national and state legislation [6] required the route be determined with formal input from county boards and landowners, a determination of need, and environmental impact assessments. The practical implementation of these regulations was so new, the opponents of the power line did not know how they might effectively oppose it. If they had, the proponents may not have known how to effectively counter that opposition. The protests led to new federal directions to consider highway right-of-ways [7] and a unique "Buy the Farm" state law [8] to mitigate future powerline controversies.

Photo of CU power line today, near Elrosa, MN [4] (taken by the author). HVDC lines have a characteristic two conductors at +/- 400 kV instead of the three for AC transmission. Each conductor here is actually two physical cables to carry more current.

About the same time, the state-owned utility company Hydro-Quebec began developing new hydroelectric projects in the far north James Bay region of that province. In 1973, Cree and Inuit nations won a court injunction against a dam and transmission line project because they had not been consulted as Canada national law required. The government of Quebec negotiated an accord, signed in 1975 with the Cree and Inuit and in 1978 with the Naskapi First Nations [9]. The main provisions were about land use rights of course, but also financial and environmental considerations.

In both cases, segments of society are asking similar questions. What justifies the need for additional energy for MSP or Montreal? Was the growth in energy use really going to be as large as proposed? What are appropriate compensations and partnerships with the people between the resource and the market? These two cases found the same answer to the latter question: compensation and partnership were both necessary.

In the last page of the last chapter, the authors concluded in 1981: "What happened with the farmers and the powerline shows a depth of rural opposition and a strength of rural resistance that is far greater than policy-makers in Washington now imagine. This resistance is not something that better public relations or technical fixes will be able to handle."

The battle as described in "Powerline" has almost no technical content. The energy war is about people, their input to a decision making process, and a rural/urban divide. Tangential to their story, the authors knew there were technological and scientific changes underway.

North Dakota has deposits of coal near the surface. Though easy to mine, they are a low grade of coal called lignite with heat content of under 20 MJ/kg, compared to 24 MJ/kg for sub-bituminous coal from Montana and Wyoming or 32 MJ/kg for Bituminous and Anthracite from Appalachia and Pennsylvania [10]. From the perspective of a thermal turbine power plant, lower energy means it is not cost effective to ship lignite by rail to Minnesota. The innovation was to build the power plant right at the "mouth" of the mine and instead ship the electric energy throughout North Dakota and Minnesota. Seven generation units capable of 400 MW or more [11] were brought online in the late 1970s and early 1980s, including the two transmitting energy via the HVDC power lines to MSP and Duluth. Along with nuclear power plants, these gigawatt-scale facilities were the choice of this era.

Another technological development was vital to this cost effective scheme. Long distance transport via alternating current (AC) to a load center like MSP is not robust. The transmission line from North Dakota to Duluth was the first one [11] to use low-cost, solid-state thyristor technology [12] invented by General Electric. In two years thyristor installations were added to a line in Vancouver, a new, second line from northern Manitoba Hydro to Winnipeg, and the CU power line [13]. Thyristors displaced previous technologies in the conversion from the AC generators and transformers to the HVDC transmission voltages. The thyristor is a silicon based semiconductor device with three terminals like a transistor. But inside it has a p-n-p-n structure (instead of p-n-p or n-p-n). The gate voltage can turn on conduction current, after which it will latch in the on state until the emitter voltage drops to zero, and will not conduct when it is back biased. Still favored today, the simple silicon implementation can conduct hundreds of megawatts at lower cost than any previous technology.

Two more quantitative aspects come up in Powerline.

Demonstration that the new facility met a public need was a policy and permitting innovation, separate from the proponent's business case. The hearings featured projections for the demand for energy, arguing that a gigawatt facility was needed immediately, and another would be needed a decade later. The demand [15] to be served by these utilities was expected to rise from 779 MW in 1974 to 3600 MW in 1990, including a reserve margin. This is an increase of a factor of 4.6 in 16 years. Testimony at the hearing confirmed they assumed demand would double as it had the decade before, obviously unrealistic on long time scales. In hindsight [16], the statewide consumption of electric energy was only 50% higher in 1990.

Alternatives to a coal power plant are barely mentioned in "Powerline". At the consumer end, electric energy is the same and theoretically should command the price of the source with the lowest marginal cost. In the conclusion, the authors defer to a 1977 book by physicist Amory Lovins [17] who advocated for a "soft energy path". Lovins describes both the impossibility of exponential growth of energy use and that a rational marketplace would assign an advantage to some technologies and withhold it from others. He combines energy physics and economics to demonstrate gigawatt scale electric facilities should be disfavored and distributed and local energy sources including new solar technology, small scale hydro, and cogeneration should be preferred. When better efficiency and lower waste are included, the soft energy path would be less expensive, lower risk, better distribute the economic benefits, and leave resources for other society priorities. Lovins was to represent the farmers and his views at a public forum on state long range energy planning in November 1979. That forum was cancelled [18], and anyway was after the power line was in operation.

It may be a surprise today, but "Powerline" does not introduce the concept of climate change at any point. It was not part of the public debate. It had been increasingly discussed in academic circles throughout the 1970s, and the book by Lovins [16] includes two paragraphs on CO2 induced climate change as one motivation for his analysis. A followup book titled "Least-Cost Energy: Solving the CO2 Problem" [19] was published the year after "Powerline", part of an increasing discussion on the science and policy of climate change.

People of the U.S. have consumed less energy per capita since the 1973 oil crisis. Our total energy consumption leveled off around the year 2000, and domestic energy production exceeded consumption in 2019. Climate change and low cost energy are major topics among policymakers. Yet America's energy war is not over.

The central U.S. is rich with the wind resource: it is especially low-cost, and has been supported by government policy, like coal in the 1970s. However, there are fewer major industrial centers; migration patterns followed coal and oil resources of the incumbent U.S. industrial regions and the midwest remained agriculture centered. Recently, HVDC transmission lines from these wind resources to the industrial and commercial orbit around Chicago have been proposed. An internet search on Plains & Eastern Clean Line, Rock Island Clean Line, Grain Belt Express, Southern Cross Transmission Line, and SOO Green Line reveals schemes to deliver energy via HVDC transmission to urban markets in Illinois, Tennessee, and Indiana. Several have been canceled, others have changed ownership in the face of opposition.

This year, the region MN, IA, SD, ND, MB has achieved the milestone that 50% of its electric energy is from carbon-neutral sources on an annual basis [20]. Wind energy is a low-cost resource throughout the region with Iowa being the first mover legislating a renewable energy standard in 1983, just two years after the publication of "Powerline". Hydroelectric energy has long been produced on the Nelson River in northern Manitoba and the Missouri River through North and South Dakota. Minnesota has included solar in its renewable portfolio standard since 2013 and has the region's two nuclear facilities [21]. Additional AC transmission lines have been built, and they are preferentially located along highway and rail corridors.

This mix of battle outcomes indicate the playing field has changed. Citizens in the energy war today are winning using the question of need, appropriate compensation, and risk to the ratepayers. Mature legal and political frameworks exist that were not available during the "First Battle".

The latest Manitoba Hydro example illustrates the situation in one package. The state-owned utility has built a new gigawatt-scale Keeyask hydro facility on the Nelson River. It is accompanied by a new HVDC transmission line to Winnipeg and new AC transmission from Winnipeg to Duluth. But the original proposal included a second gigawatt facility. Essentially all the energy was intended for export, not for Manitoba. The Public Utility Board [22] supported Keeyask but said the business case for the second facility was insufficient and put Manitoba Hydro's customers (i.e. the entire province) at risk of increased electrical rates. The government's political decisions followed the board's recommendations. They further emphasized partnership with the First Nations to build and operate Keeyask and also improvements in energy efficiency [23] as the alternative to investment in the second facility.

Many readers of this forum are students seeking technical careers that will impact society, or are training STEM students and future policymakers from introductory courses to advanced degrees. We instill technical skills, ability to process out-of-domain knowledge, enthusiasm for quantitative analysis, and the physics of energy.

Achieving a >80% carbon free electric grid requires new approaches and technologies. The cost for solar and wind generation have inexorably become the low-cost form of

electricity generation in many parts of the country [24]. Like energy demand, these sources are variable but also predictable. Gas, coal, nuclear, or hydro generation is increased or decreased to match supply to demand.

The fossil fuel fraction can be decreased if cost-effective battery storage becomes available on a utility scale. Great River Energy, the current owner of CU power line, will partner with grid battery startup Form Energy to be their first deployment [25], in service by 2023. The pilot is specified to deliver 1 MW for up to 150 hours, well matched to weather cycles typical of wind generation and cold-climate indoor heating. The technology is aimed at utility scale replacement of peaking fossil fuel plants. The job posting page for this battery company [26] features 14 of 22 positions requiring science and engineering degrees where at least introductory physics courses are required.

The predictability of wind, solar, and demand is another opportunity for those with a physics training. The energy yield is predicted a day ahead and real time through meteorological data collection, simulation, and quantitative analysis. The better the physical predictions, the better the deployment of batteries, fossil fuel, nuclear, and hydroelectric can be managed to compensate. Additional innovations could better manage demand, shifting energy use from time to time of surplus production. Then fewer transmission lines or gigawatt-scale fossil fuel facilities would be needed, lowering reserve margins, cost, and CO2 emissions. Dynamic demand management at the individual customer level requires data analysis, sensors, and control systems that number in the millions of channels. This is the skill-set of experimental particle and nuclear physics, for example. One of the positions among the job postings in [26] seeks a M.S. level professional with "deep expertise in scientific data analysis".

The APS and the Forum on Physics and Society has already been leading the approach. Looking back on the 1974 APS report on energy efficiency [27], Robert Socolow remarked [28] that a main goal was to promote that physicists should also work on problems related to energy use, and not just energy supply such as nuclear facilities and solar panels. The accompanying Physics Today article [29] contains a half page of selected research opportunities. A second report offering a "fresh look" at the subject of efficiency was published in 2008 [30]. In the same year, the Forum of Physics and Society sponsored the first of four workshops on sustainable energy [31] to encourage physicists to apply their skills to these topics. These workshops are advancing a wide range of physical technologies in addition to process and analysis technologies.

Great River Energy is the current owner of the CU transmission line and the Coal Creek Power Station. They announced [31] the coal power plant would be shut down and dismantled in 2022 and the contract with the lignite mine terminated. Compared to other energy generation and demand reduction investments, they judge this is no longer a cost effective facility.

The transmission line had received a 130 M$ upgrade in 2019 [32]. It could transport 1 GW of wind energy to the MSP market [33]. Already in 2010 the other HVDC transmission line had a new owner and was repurposed to deliver wind energy.

Some stalled HVDC transmission initiatives listed earlier may yet be built. But as with the eponymous power line, there would be no direct benefit to the communities between. Instead, governments and residents in the newly energy-rich regions may advocate that business and industry should migrate to the Interstates 35+29 and Mississippi + Missouri River corridors. Some industries will find advantage in energy price fluctuations that accompany variable wind and solar energy supply. Others may find that a grid starting at 50% carbon free requires less additional investment to achieve their completely carbon free goals.

America's energy war continues.

Rik Gran is professor in the Department of Physics and Astronomy at the University of Minnesota Duluth, and Fellow of the American Physical Society. As a music and physics double major, he took the undergraduate quantum mechanics course from Mike Casper in 1994.

ENDNOTES

[1] The name CU is a contraction of two organizations: Cooperative Power Association and United Power Association. After a sequence of mergers, the power line is now owned by Great River Energy, still an association of member coops and collectively the second largest utility in Minnesota. The power line runs from the Coal Creek Station in Underwood, ND to Buffalo, MN.

[2] Barry M. Casper and Paul D. Wellstone, "Powerline, The First Battle of America's Energy War", 1981 University of Massachusetts Press, reprinted 2003 University of Minnesota Press. Additional information from other sources is available on the web and in newspaper records from the time.

[3] The APS FPS has an article on its own history at https://www.aps.org/units/fps/history.cfm

[4] This photo is taken from Stearns County near Elrosa, one center of protests. In the background is the 78 MW Black Oak Windfarm, built in 2016 by a collection of publicly owned municipal utility companies.

[5] Page 7 of "Powerline" reprints messages to congress from presidents Nixon (18 April 1973), Ford (26 February 1976), and Carter (20 April 1977) highlighting domestic sources of energy. Policy development leading to Nixon's official message coincided with the 1972 discussions to add a coal mine and transmission line to meet utilities future needs. This turned out to be in the run-up to the oil embargo that started in October 1973. The text can also be found in the congressional and newspaper records, such as https://www.nytimes.com/1973/04/19/archives/excerpts-from-nixon-message-developing-our-domestic-energy.html (behind a paywall, accessed on 5 December 2020).

[6] Much is described throughout "Powerline" but a few are extracted here with useful search terms. The first National Environmental Policy Act was passed in 1970. Minnesota's 1973 Environmental Policy Act is modeled after it and required environmental impact statements and also established a Minnesota Environmental Quality Council. Also in 1973 a Powerline Siting Act changed how facility and transmission line locations are selected, and in 1974 the creation of the Minnesota Energy Agency by governor's executive order.

[7] H.R. 11389, "A bill to amend title 23 of the United States Code to clarify policies relating to the accommodation fo utilities on Federal-

aid highway rights-of-way", 1978, introduced by Rep. Al Quie. Quie was elected governor of Minnesota the same year and served from 1979 to 1983.

[8] The 1977 "buy the farm" law is Minnesota Statute 216E.12 Sub.4, introduced by Sen. Gene Merriam, augmenting eminent domain law for specific cases of transmission line siting. Note, both this and [7] were introduced during the protests, not before. This statute may still be unique in the nation and was upheld in 2015 by the Minnesota Supreme Court in the case Docket A13-1474 Great River Energy v. Swedzinski, 4 March 2015 opinion by Chief Justice Lorie Gildea. The case involves transmission lines from wind farms in South Dakota to Minnesota which have now been completed.

[9] Especially the essays by Romauld Wera and Thibault Martin "The Way to Modern Treaties: A review of Hydro Projects and Agreements in Manitoba and Quebec" and Renée Dupuis "Should the James Bay and Northern Quebec Agreement Serve as a Model Agreement for Other First Nations?" both in "Power Struggles: Hydro Development and First Nations in Manitoba and Quebec", Martin Thibault and Steven Hoffman, eds., University of Manitoba Press, 2009. Also for a factual review see https://en.wikipedia.org/wiki/James_Bay_and_Northern_Quebec_Agreement .

[10] For example https://hypertextbook.com/facts/2003/JuliyaFisher.shtml harvested 5 December 2020. On the society end, also consider the music composition "Anthracite Fields" by Julia Wolf 2014 (awarded Pulitzer Prize for Music 2015).

[11] Extracted from https://lignite.com/mines-plants/power-plants/ on 5 December 2020.

[12] Caceras, "Square Butte HVDC transmission system is completed" abstract from Transmission and Distribution, vol. 29, issue 7, July 1977. Accessed from https://www.osti.gov/biblio/7253641-square-butte-hvdc-transmission-system-completed-kv on 5 December 2020.

[13] For example, https://ethw.org/Milestones:SCR/Thyristor,_1957 accessed 5 December 2020.

[14] Of course Wikipedia has a list https://en.wikipedia.org/wiki/List_of_HVDC_projects sorted by continent and then by date. Accessed 5 December 2020.

[15] Discussion and table given on page 93 of "Powerline".

[16] Using https://www.eia.gov/totalenergy/data/annual/pdf/sec8_17.pdf harvested 11 November 2020. This is the statewide energy demand, not just these specific utilities. The excess energy delivered on the CU power line was sold to other utilities.

[17] Amory B. Lovins, "Soft Energy Paths: Toward a Durable Peace", Friends of the Earth International [distributed by Ballinger Publishing Company], 1977.

[18] Discussion on page 291 of "Powerline"

[19] Florentin Krause, Wilfrid Bach, L. Hunter Lovins, Amory B. Lovins, "Least-Cost Energy: Solving the CO2 Problem", Brick House Publishing, 1982.

[20] Calculated from https://www.eia.gov/electricity/data/state/ and https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-manitoba.html

[21] The two nuclear facilities in Minnesota began operations in 1971 (Monticello) and 1973 (Prairie Island), prior to the CU power line protests. Another facility was completed in Iowa in 1975 (Duane Arnold) and was scheduled to cease operations in October 2020, despite operating permits to 2034. Its largest customer bought itself out of power purchase agreements to favor of less expensive sources of energy. http://newsroom.nexteraenergy.com/2018-07-27-NextEra-Energy-Resources-and-Alliant-Energy-agree-to-shorten-the-term-of-the-Duane-Arnold-Energy-Center-power-purchase-agreement-Alliant-Energy-customers-to-save-hundreds-of-millions-of-dollars Instead, the derecho wind event on 10 August 2020 damaged the cooling towers and ending production early.

[22] Public Utilities Board of Manitoba "Report on the Needs For and Alternatives To (NFAT); Review of Manitoba Hydro's Preferred Development Plan", June 2014.

[23] The Manitoba Government Press Release https://news.gov.mb.ca/news/index.html?item=31611&posted=2014-07-02 (2 July 2014) accessed 5 December 2020. Also consider the essays in Part III of reference [9] above.

[24] a privately owned consulting agency Lazard's assessment https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/ and one by the U.S. government Energy Information Administration https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf accessed 5 December 2020. Both reports have been updated every year for over a decade.

[25] Two press releases, Great River Energy https://greatriverenergy.com/long-duration-battery-project-in-the-works/ (17 June 2020) and Form Energy https://formenergy.com/wp-content/uploads/2020/05/Form-Energy_-GREPilotPress-Release.pdf (7 May 2020) accessed 5 December 2020.

[26] Job website https://jobs.orbit.mit.edu/companies/form-energy accessed 4 December 2020. Text from a specific Senior Data Engineer post is quoted. It also says they are also looking for "A humble professional who is willing to ask for help when necessary but has the confidence to take on complex tasks."

[27] "Efficient Use of Energy: The APS studies on the technical aspects of the more efficient use of energy", K.W. Ford et al., eds, American Institute of Physics Conference Proceedings, vol. 25, 1975 from conference July 1974, Princeton, NJ. Confusingly, citations differ on who contributed editorial and authorship to the 1975 proceedings, including or not Robert Socolow, Walter Carnahan, and even Barry M. Casper. Perhaps because writing was still a work in progress and credit for editor duties was not yet final, and/or there are multiple reports and excerpts drawn from the same 1974 conference.

[28] Robert Socolow, "Reflections on the 1974 APS Energy Study", Physics Today vol. 39 issue. 1 (Jan 1986) p. 60

[29] Physics Today with assistance of Robert H. Socolow, "Efficient Use of Energy", Physics Today, August 1975, p. 23.

[30] American Physical Society, "Energy Future Think Efficiency, How America can Look Within to Achieve Energy Security and Reduce Global Warning", APS Report, September 2008.

[31] Physics of Sustainable Energy conferences, at the University of California Berkely in 2008 AIP Conference Proceedings 1044 (2008); in 2011 AIP Conference Proceedings 1401 (2011); in 2014 AIP Conference Proceedings 1652 (2015); and at the University of Chicago in 2016, AIP Conference Proceedings 1924 (2018)

[31] Great River Energy Press Releases https://greatriverenergy.com/major-power-supply-changes-to-reduce-costs-to-member-owner-cooperatives/ , 7 May 2020 and https://greatriverenergy.com/plant-closure-renewable-plans-detailed-at-industry-event/ 14 October 2020.

[32] Great River Energy Press Release https://greatriverenergy.com/critical-transmission-upgrade-finishes-strong/ 13 June 2019. Also the Thomas Dolby song "Windpower" from the album "The Golden Age of Wireless", Capitol/EMI records, 1982.

[33] As a followup to Ref. [2] and Ref. [9], consider the rural/urban divide and resistance to wind energy described by Jaume Franquesa Bartolome, in "Power Struggles: Dignity, Value, and the Renewable Energy Frontier in Spain", Indiana University Press, 2018.

Were the Polls Wrong?

Richard Wiener, Research Corporation for Science Advancement

A powerful post-election meme is that the polls were way off … again! For instance, New York Times columnist Bret Stephens writes, "…it's been two massive [polling] failures in consecutive presidential elections. The failure will be partially obscured by Biden's ultimate victory, but there ought to be some accountability for the industry." In this article, I'll argue it's not the polls that were wrong, but instead expectations about how accurate polls should be.

Polls are intended to estimate voting preferences. To make these estimates, polling organizations (pollsters) use different data gathering methods, including live call, online, or robocall surveys, and various data analysis techniques, including different sample sizes, demographic categories, weighting of categories, and methods to identify likely voters. Since the voting preferences of a large population are influenced by a complex set of phenomena, which can change rapidly and unexpectedly, polls almost always miss the actual result of an election by some margin. How good are they typically?

	2016 Results	2020 Results	RCP Ave	PEC Ave	538 Ave	Upshot Ave
National	+2.1	+4.5	+7.2	NA	+8.4	+8
Maine	+3.0	+9.1	NA	+13.0	+13.0	NA
N. Hampshire	+0.37	+7.3	NA	+8.0	+11.1	+11
Minnesota	+1.5	+7.1	+4.3	+9.3	+9.2	+10
Michigan	-0.23	+2.8	+4.2	+7.5	+7.9	+8
Nevada	+2.4	+2.4	+2.4	+6.0	+5.3	+6
Pennsylvania	-0.72	+1.2	+1.2	+5.0	+4.7	+5
Wisconsin	-0.77	+0.62	+6.7	+8.5	+8.4	+10
Arizona	-3.5	+0.30	+0.9	+3.0	+2.6	+3
Georgia	-5.2	+0.24	-1.0	+1.5	+1.2	+2
N. Carolina	-3.7	-1.3	-0.2	+2.0	+1.8	+2
Florida	-1.2	-3.3	+0.9	+3.0	+2.5	+2
Texas	-9.0	-5.5	-1.3	-2.7	-1.1	-2
Ohio	-8.1	-8.1	-1.0	-2.8	-0.8	0
Iowa	-9.4	-8.2	-2.0	-1.0	-1.3	-1
Average Miss			2.9	4.0	4.2	4.6

Table 1. The results of the 2016 and 2020 national popular vote and presidential elections in the fourteen closest states (in 2020), and 2020 polling averages from four different websites: Real Clear Politics (RCP), the Princeton Election Consortium (PEC), FiveThirtyEight (538), and the New York Times Upshot (Upshot). Numbers are reported in terms of Biden's (or Clinton's for 2016) percentage of votes minus Trump's percentage of votes. NA means the website didn't calculate an average of polls for that race. Highlighted numbers indicate a 2020 result that shifted blue relative to a 2016 result.

The FiveThirtyEight (538) website maintains a database which includes polls conducted in the final three weeks of House, Senate, gubernatorial, and presidential general election campaigns, and presidential primaries and caucuses since 2000 (some polls in the database are from as far back as 1998). One of the statistics 538 tabulates is a pollster's average miss, calculated as the difference between the polled result and the actual result for the margin separating the top two finishers in the race. Of the 32 pollsters with 50 or more polls in the database, 22 of them miss on average by 4-6 points. The pollster with the lowest average miss is ABC/Washington Post at 2.8 points for 73 polls prior to the 2020 election. American Research Group has the highest average miss at 7.4 points over 273 polls. And, of course, this statistic gives no indication of the distribution of misses. For example, even though ABC/Washington Post misses by the smallest margin on average amongst the 32 most prolific pollsters listed by 538 and was off by only 1.4 points for the Florida presidential race in 2020, the firm missed Wisconsin by nearly 17 points.

In other words, any given poll is typically off by roughly five points. If a poll estimates that candidate A leads candidate B by 5 points within three weeks of the election, it should be no surprise if A wins by a landslide (defined as a double-digit margin) or B wins a nail biter. So why bother paying attention to polls?

Over the past two decades, it's become common for analysts such as Nate Silver at 538, Sam Wang at the Princeton Election Consortium (PEC), and Nate Cohn at the New York Times Upshot to average polls in order to cancel out random errors in individual polls due to different sampling methods, data analysis techniques or other causes. Although averaging polls won't eliminate systematic errors by pollsters, the hope is that averaging nonetheless yields a better estimate of the state of a race than an individual poll usually gives.

An obvious question is what kind of average is best to use, or does it even matter given the level of uncertainty in polls. The website Real Clear Politics (RCP) takes the mean of polls within the last two or so weeks before an election, typically 3-8 polls, from a select set of pollsters. PEC takes the median of the last few polls but from a broader set of pollsters. 538 uses a weighted average of polls from a very broad range of

pollsters, with weighting based on the past performance of the pollster, sample sizes, historical bias, and recency of the poll, among other factors. The Upshot also uses a weighted average. For many races these different averages are similar, since they use an overlapping set of polls, but occasionally the different averaging methods yield some notable differences. Table 1 lists the actual results of the 2020 presidential race and the final averages of RCP, PEC, 538, and the Upshot. 2016 results are also included for later discussion.

The 2020 polling averages from these four websites did a little better than individual pollsters typically do, but not much better, except for RCP's average. The average miss ranged from 2.9 to 4.6 points. RCP did the best due to their limited selection of pollsters, which included several of the better performing firms in 2020 such as Rasmussen Reports, Trafalgar Group, and Susquehanna, even though these same firms have not been the most accurate pollsters in previous elections, with average misses of 5.3 (722 polls), 5.6 (48 polls), and 5.8 (38 polls), respectively. Averages from the other websites include polls from these firms, but their effect is not as pronounced due to the larger inclusion of other pollsters or by receiving less weight due to poorer performance in past elections. Whether a matter of chance in how RCP calculated its averages or better insight as to which pollsters to select, an average miss of only 2.9 points is better than the average misses of 31 of the 32 most prolific pollsters in the 538 database. RCP averages nailed Nevada and Pennsylvania and came within 2 points in Michigan, Arizona, Georgia, and North Carolina, which constitutes impressive agreement.

However, the misses for all four websites do not appear to be the result of random errors alone. Every average from PEC, 538, and the Upshot overestimated the voting preference for Biden. Nine out of thirteen averages from RCP overestimated Biden's strength and only two averages (Georgia and Minnesota) overestimated the preference for Trump. There was a systematic Democratic bias in the presidential polls in 2020. Pollsters will need to determine the sources of systematic error, and compensate for them in future polling, if possible.

But contrary to Stephens' view that Biden's victory obscures the failure of the polls, I think this year's systematic overestimation of Biden's winning margin obscures the success of the polls. The polls clearly predicted a blue shift in the electorate by estimating that the national popular vote and the fourteen most competitive states had shifted blue relative to 2016. Indeed, the national popular vote shifted from +2.1 blue in 2016 to +4.5 blue in 2020, and eleven of the fourteen states listed in Table 1 also shifted blue. Only one state, Florida, shifted red, and it did so by only 2.1 points. Nevada and Ohio didn't shift either way, but Maine, New Hampshire, Minnesota, Michigan, Pennsylvania, Wisconsin, Arizona, Georgia, North Carolina, Texas, and Iowa were all blue shifted in 2020. No state flipped red and five states, and one congressional district in Nebraska that awards an electoral vote, flipped blue. The polls identified a clear trend across the national electorate that proved decisive in the outcome of 2020 compared to the outcome of 2016.

It is a subjective judgment as to whether one considers the polls a success, since they correctly estimated a broad blue shift, or if one considers the systematic overestimation of this shift as a failure. But given the historical accuracy of polls, which polls in 2020 were roughly consistent with, it is impressive that the polls correctly predicted the most important overall trend in the 2020 presidential electorate. Indeed, the polls were worth paying attention to.

Richard Wiener
Research Corporation for Science Advancement
rwiener@rescorp.org

The Precipice: Existential Risk and the Future of Humanity

by Toby Ord (Hachette, 2020). 480 pages, $13.99, ISBN-13: 9780316484893

I quote: "This book argues that safeguarding humanity's future is the defining challenge of our time." However, the prophecy of a precipice may be premature. *The Precipice* is long and summarizes a large amount of work. It's hard to do it justice in this brief review. For a fuller review, with page numbers, please email me.

Chapter 1: Standing at the Precipice. I applaud the expansive attempt at a manifesto: That humanity stand at the brink of a metaphorical precipice. "Humanity" seems to be mainly civilization during the past 10,000 years, including written language. A litany of risks is discussed, together with numerical estimates, frequently presenting the associated uncertainties only verbally. I prefer error bars or confidence intervals.

Precipice states "unforeseen anthropogenic risks" are twenty times more probable than nuclear war or climate change risks; I ask how to evaluate unforeseen risks. As an example that experts can be wrong, Ernest Rutherford is quoted that the notion that nuclear energy can be harnessed is "moonshine." *Precipice* might point to an expert being right after a century (Albert Einstein, gravitational waves.). The book observes that even core scientific certainties--e.g. that objects have determinant locations--have been wrong before. The uncertainty principle answers this. I note that the perception of risk, whether regarding climate change or effective measures against an epidemic, depends strongly on the politics of the perceiver, at least in the USA.

Precipice does resist the temptation to do sophisticated mathematical analyses, even though the basic data is poorly defined. Ord states "…To reach other stars and settle their planets…we know of no fundamental obstacles ... then the whole galaxy opens to us". Alas, simple calculations show that a one-way trip could easily exceed the lifetime of the civilization that started the trip, so a *deus ex machina* is required. Ord presumes that "with enough time we can end these horrors (malaria and HIV)" but some diseases may always be part of the human condition.

Chapter 2: Existential Risks. Although many species have gone extinct during this human-dominated era, this book is mainly about only one species. *Precipice*: "…millions of deaths must be much worse than thousands of deaths…," but poet John Donne offers a different view: "Any man's death diminishes me, because I am involved in mankind, and therefore never send to know for whom the bell tolls; it tolls for thee."

Are we alone in the universe? Ord considers the Drake equation. It multiplies the probabilities of a star having a planet of suitable mass, the planet being at the "Goldilocks" distance from its star, etc., to obtain the likely number of extra-terrestrial civilizations in our galaxy. According to *Precipice*, we are alone. Medieval people would agree, but reasonable people are today devoted to searching for life beyond Earth and the topic continues to attract scientific interest, as in an article titled "The astrobiological Copernican weak and strong limits for intelligent life" published in The Astrophysical Journal for June 15, 2020.

Chapter 3: Natural Risks. Ord analyzes the asteroid threat, a good example of a risk that can be estimated. The Chicxulub crater was caused by an asteroid or comet which led to the extinction of much life on Earth.

Precipice concludes that natural risks are difficult to estimate, but are the order of a thousandth of anthropogenic risks. The author specifically classes pandemics as "anthropogenic."

Chapter 4: Anthropogenic Risks. There are no numerical estimates. Precipice might have mentioned the Bulletin of the Atomic Scientists' clock, whose hands are uncomfortably close to midnight.

Chapter 5: Future Risks. These include pandemics. Because the was written before the COVID-19 pandemic, it is interesting to read about these possibilities. Alas, there are no numerical estimates. *Precipice* states "the case for existential risk from Artificial Intelligence …is the most speculative case for a major risk." The discussion of AI is good. I note that we already use a form of AI as artificial memory, namely writing. Plato and Socrates are on record as challenging artificial memory, yet it is essential to modern civilization. A survey published in *The Economist* (2000) discusses AI's limitations and concludes that "the dreams of high summer will fade in the autumnal chill." Thus, despite *Precipice*, AI appears not to be a risk.

Chapter 7: Safeguarding Humanity. Ord writes "the best futures…will require technologies we have not yet reached, such as cheap clean energy." But to me it's unclear that simultaneously "cheap" and "clean" energy is possible.

Chapter 8: Our Potential. The book notes that horseshoe crabs have an unbroken lineage of 450 million years — "unbroken" in that we can trace them in the fossil record, although they have changed over that time. Ord notes that we should expect the brightening of the Sun to slow the Earth's plate tectonics, but a reference is lacking. Since plate movement is attributed to convection *inside* Earth, more explanation of how the Sun can affect it would be welcome.

Toby Ord would surely be a fascinating companion on long hikes. His book deserves to be accessible to a wider audience, which it could be were it published in shorter form, perhaps as an article in *Science* magazine. As for the claim that "safeguarding humanity's future is the defining challenge of our time," my verdict is the Scottish: Not Proven.

Leonard Finegold
Department of Physics, Drexel University
L@drexel.edu

Losing Earth: A Recent History

Nathaniel Rich (MCD/Farrar, Straus, and Giroux, New York, 2019). 204 pages. ISBN: 978-1-250-25125-1. $16.00

In *Losing Earth: A Recent History*, Nathaniel Rich recounts the story of climate change's rise as a political issue in the 70s and 80s. In the process he introduces the reader to the major figures of this movement, shedding light on people like Rafe Pomerance, Jim Hansen, and many other characters who are probably unfamiliar to the average person. The actions of these people have had an enormous impact in the decades following their work.

Unlike many books about climate change, *Losing Earth* contains very little discussion of the science of climate change. While surprising at first, upon reflection this makes sense given Rich's purpose in writing the book. Contrary to the claims of certain interest groups, the science of climate change is well-understood. *Losing Earth* presents the evolution of political and public opinions on climate change and climate policy, which is much more variable, and by extension much less cohesive. By not presenting these two topics together, Rich avoids entangling the validity of the science with the fluid nature of politics. In fact, he argues in the introduction that it was better understood by the general public during the 80s than it is today, a point that I found difficult to question after reading the book.

Another surprising feature of *Losing Earth* is its blunt criticism of "the politicization of the climate issue," which Rich calls "a polite way of describing the Republican Party's stubborn commitment to denialism." This book is most definitely not directed to an audience of climate skeptics, let alone climate deniers. I found this to be both an asset and a hinderance to the book. On the one hand, this allows for a more frank discussion of the issue than usually occurs when addressing climate change. The victories, defeats, mistakes, and misdeeds of the past are laid forth without equivocation. On the other hand, it means that readers of a certain political identity who may have been open to persuasion will be more likely to reject the evidence of climate change. It potentially makes climate change into an issue of personal identity, rather than of science. While it is clear that this attitude is present throughout *Losing Earth* , its most overt manifestations are relegated to the introduction and conclusion. The main body of the book focuses primarily on recounting the events that shaped climate change as a political issue.

Rich splits the story into three parts. He begins by introducing us to the major players. Rafe Pomerance, with his experience as an environmental lobbyist, sets things into motion after reading an inconspicuous government report that mentions the possibility of climate change. His meeting with Gordan MacDonald, a member of a group of scientists that advises the US government known as the JASONs, led to the National Academy of Sciences ordering an assessment of the problem of climate change. The results of this assessment, known as the Charney report, relied heavily on computer simulations of climate patterns with higher atmospheric concentrations of CO2, produced by Jim Hansen. The Charney report sent shockwaves through the academic, political, and economic leaders of the country. Even Exxon, whose predecessor had started studying the effects of burning fossil fuels on the carbon content of the atmosphere in the 50s, accepted that regulations would most likely be passed as a result of the Charney report. Despite setbacks from the Reagan administration, the first part of the book ends on a hopeful note, with many of Reagan's deregulatory policies having been rejected by Al Gore's Congressional hearings placing climate change firmly in the public consciousness.

Unfortunately, this momentum would not hold up. Part two of the book describes the uphill struggle to maintain pressure to address climate change. Although new reports continued to be published that stressed the urgency of climate change, prominent scientists involved in the writing of those reports downplayed the severity of the issue in public. This fueled the Reagan administrations arguments for rolling back environmental regulations and prompted fossil fuel companies to backtrack on their pledges to combat climate change. Although Pomerance was successful at using the newly-discovered "ozone hole" to renew public concern about climate change, his efforts fell on rocky soil. Many statements were made and international agreements signed, but few policies actually changed. The last section of the book tracks the decline of climate policy to its current state. Much of it revolves around John Sununu, George H. W. Bush's chief of staff. He did not trust climate scientists, and did everything in his power to poison any attempt to create meaningful climate policy. As a result, the Bush administration was full of empty platitudes paying lip service to climate change, with no intention of heeding the science. This opened the door to the erosion of the political consensus on the validity of climate change, and the outright denialism that we see today.

If there is a central moral of the book, it is this: complacency and excessive caution have led, both in the past and in the present, to the worsening of climate change. This raised some interesting questions for me. As scientists, we are trained to qualify our assertions. This is a good thing for the scientific enterprise. It is one of the many ways we try to maintain as much objectivity as possible in our work. This, however, is detrimental to the communication of ideas to the public. As has been seen time and time again in this book and in the present day, this language that is normally recognized as intellectual honesty by other scientists leaves room for dishonest individuals to muddy the waters, saying that "there isn't a consensus" or that "the science is unclear," when in reality the research is very clear. So, we are led to the question: do we, as scientists, need to change the way we present our results to the public in order to remove the possibility for equivocation?

Quinn Campagna
University of Mississippi
qcampagn@go.olemiss.edu