

PHYSICS & SOCIETY

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

Note from the Editor

It is April and the presidential primary season is well underway way in both fascinating and distressing ways. While climate change has come up for discussion among the candidates, there is almost no mention of federal funding for science, serious discussion of science policy or the long history of R&D spurring US innovation and economic development. The question becomes what are we, as physicists actively engaged in the intersection of physics and society, prepared to do?

With that in mind, I am pleased that this issue of the newsletter focuses on scientific innovation and public policy. There are two articles of personal reflection on what it is like to be a physicist working in public policy. There is also a letter outlining the history and efficacy of incentivizing innovation. In the News of the Forum section, we have the results from our recent election to the Executive Committee, the announcement of our FPS-sponsored award recipients, a report from our POPA representative, a listing of sessions

that FPS sponsored at the April meeting, and a request for your nominations to APS Fellowship. There is an announcement of an upcoming workshop on the physics of sustainable energy. We also have a summary of a recent AAAS session on the future of US science. Finally, we have a fascinating reprint from the Bulletin of the Atomic Scientists of a first person account from a recent visit to the Fukushima Daiichi nuclear generating complex. As always we end with two book reviews from our book Editor, Art Hobson.

Lastly, my three year term as Editor is rapidly coming to a close and we have begun searching for someone to replace me. It has been one of the most rewarding jobs I have ever done and if you are interested in becoming Editor please contact me and I would be happy to fill you in on the details.

Happy Reading,
Andrew

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To the Editor

Can incentive prize competitions stimulate breakthroughs in basic and applied science? How effective are prize competitions, and in which domains of research and technology development? XPRIZE Foundation has been exploring these questions in a practical sense for over two decades. Though XPRIZE is an independent not-for-profit, its success at supporting science and technology communities has attracted growing attention from national government agencies, independent charities, and science oriented foundations. The incentive prize model, in which only successful demonstration of a performance target is rewarded, is gaining traction in these quarters. This may be, at least in part, a response to the advancing era of transparency and accountability in research, grant-making, and government generally. Recently-announced XPRIZE competitions present opportunities for the physics and physical science communities in particular.

The incentive prize model (sometimes called inducement prize model) is not new. Its use in catalyzing solutions to wicked problems goes at least as far back as the famous longitude prize offered in 18th century Britain for a method of deducing a ship's longitude at sea. Other well-known instances include the Orteig Prize for the first non-stop flight between Paris and New York (won by Charles Lindbergh in 1927, and inspiration for the creation of XPRIZE in 1995), and the Sikorsky Prize for human-powered helicopter flight, framed in 1980 and claimed by Aerovelo in 2012. The range and history of prizes raises natural questions in today's research context about which problems are best suited to be solved or having solutions advanced by a prize competition.

XPRIZE designs and operates prize competitions to tackle well known wicked problems in four domains: learning, healthcare, (space) exploration, and energy and environment. By way of example, the ongoing Google Lunar XPRIZE, a \$30 million to land a lunar rover on the moon, and the Qualcomm Tricorder XPRIZE for rapid, hand-held medical diagnostics, have benefitted from strong participation from physical scientists and engineers keen to answer fundamental questions, push experimental performance, and develop integrated hardware for research and technology development.

Two recently-announced competitions provide a particular opportunity for the physics community. The first is the NRG COSIA Carbon XPRIZE, a \$20 million competition for conversion of post-combustion CO₂ into higher value materials and products. Mitigation, capture, and use of industrial carbon emissions may already be familiar to your readers in light of the APS Panel on Public Affairs 2011 report on direct air capture of CO₂. The second is the Shell Ocean Discovery XPRIZE, a \$7 million competition to demonstrate autonomous mapping of the ocean floor to spatial resolutions orders of magnitude beyond what has been achieved to date. Both competitions are accepting submissions from any interested team until July 2016 and September 2016, respectively.

The research literature on the efficacy and value of prize competitions is rich and growing. But beyond an award for best performance, or a solution search to a specific problem, the prize competition format at its best can drive inspiration, attract creative talent into a problem space, and showcase the personal and professional journeys of the scientists and engineers focused on finding solutions. It's fair to say that the physics community is not known for its storytelling. That may be changing somewhat, with recent productions such as *Intersellar*, *Cosmos: A Space-time Odyssey*, *Particle Fever*, and even the recent gravity waves announcement from LIGO, each tackling the physics storytelling challenge head-on. Still, the excitement and challenge of a prize competition may hold tremendous potential to help physicists tell their stories, and to lionizing the work of some of our most creative contemporary minds.

Marcius Extavour

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References on use and efficacy of prizes:

- [1] L. Kay, Opportunities and Challenges in the Use of Innovation Prizes as a Government Policy Instrument, *Minerva* 50:191–196, 2012.
- [2] L. Jeppesen, K. Lakhani, Marginality and Problem-Solving Effectiveness in Broadcast Search, *Organization Science*, Vol. 21, No. 5, September–October 2010, pp. 1016–1033
- [3] S. Magnuson, More Government Agencies Using Challenge Prizes to Tackle Tough Technology Problems, *National Defense*, January 2015, p.28
- [4] T. Kalil, Prizes for Technological Innovation, *Brookings Institution discussion paper*, 2006.
- [5] And the winner is... Capturing the promise of philanthropic prizes, *McKinsey & Company*, 2009.

BECOME THE NEXT EDITOR OF THIS NEWSLETTER

Being the Editor of this newsletter the past three years has been one of the most rewarding things I have ever done. My term ends with the July issue and the search has begun for someone to replace me for a three-year term starting with the October issue. The Editor is responsible for identifying content with the support of an outstanding Editorial Board. APS staff handles the layout. The newsletter is published quarterly and presents letters, commentary, book reviews, and non-peer-reviewed articles on the relations of physics and the physics community to government and society. *Physics and Society* also carries news of the Forum and provides a medium for Forum members to exchange ideas. If you are interested in becoming the next Editor, please email me at azwicker@princeton.edu and I can fill you in on the details.

CONGRATULATIONS TO NEW AWARD RECIPIENTS

2016 Joseph A. Burton Forum Award

ERNEST MONIZ, U.S. Department of Energy

For outstanding contributions in government service to advancing national energy and science policy over two decades and to reducing the threat of nuclear proliferation through key roles in disposition of Russian nuclear materials in the 1990s and negotiation of the nuclear agreement with Iran in 2015.

2016 Leo Szilard Lectureship Award

JOEL PRIMACK, University of California, Santa Cruz

For a crucial role in establishing the Congressional Science and Technology Policy Fellowships.

WORKSHOP ON PHYSICS OF SUSTAINABLE ENERGY

The fourth FPS sponsored workshop on Physics of Sustainable Energy (PSE-IV) will be held this year in the Midwest region, at the University of Chicago, June 17-18, 2016.

The PSE-IV workshop will continue the tradition of the three successful workshops held in 2008, 2011 and 2014. The workshop will consist of lectures from experts on current global energy landscape, sustainable energy technologies and innovations. It is aimed at college professors, researchers and students interested in energy issues. A contributed poster session is also envisioned.

For details on the workshop program and registration information, please visit the workshop website. We look forward to seeing you at the workshop in Chicago.

Organizers:

Pushpa Bhat, Fermilab (Chair, FPS Events Committee)

Robert Rosner, University of Chicago

George Crabtree, Argonne National Laboratory

Robert Knapp, Evergreen State College

ELECTION RESULTS

Congratulations to the winners of the elections to positions on the Forum on Physics & Society Executive Committee! Thanks to all nominees for these executive committee positions and to the nominating committee for designating such strong candidates and we look forward to the contributions the new members will make toward the development of FPS.

Vice Chair:Beverly K Hartline

Secretary/Treasurer:Tony Fainberg

Members at Large:Frank von Hippel

Vivian O'Dell

POPA Rep:Phil Taylor

Forum Councillor:Pushpa Bhat

CALL FOR NOMINATIONS TO APS FELLOWSHIP

Any active APS member is eligible for nomination and election to Fellowship. The criterion for election is exceptional contributions to the physics enterprise; e.g., outstanding physics research, important applications of physics, leadership in or service to physics, or significant contributions to physics education. Fellowship is a distinct honor signifying recognition by one's professional peers.

Instructions for nomination can be found at: <https://www.aps.org/programs/honors/fellowships/nominations.cfm>

The FPS Deadline for APS Fellowship Nomination is Wednesday, June 1, 2016.

FPS SESSIONS AT 2016 APRIL MEETING

SATURDAY, APRIL 16 • 10:45 AM • ROOM 150G

Recent Discoveries in Planetary Science and their Potential Impacts on Physics and Society

Invited Speakers: Matthew Stanley, Peter Behroozi, Lynnae Quick

SATURDAY, APRIL 16 • 1:30 PM • ROOM 150G

Modernizing Nuclear Weapons

Invited Speakers: Donald Cook, James Acton, Daryl Press

SUNDAY, APRIL 17 • 10:30 AM • ROOM 150G

Politicizing Science: Benefits and Costs

Invited Speakers: Rush Holt, Spencer Weart, Joel Primack

SUNDAY, APRIL 17 • 3:30 PM • ROOM 150G

Fracking and Physics

Invited Speakers: J. Quinn Norris, Arthur McGarr, Shawn Maxwell

The February 2016 meeting of POPA saw the arrival of a new batch of members to replace those whose terms had expired in December, and of a new batch of issues to address. I was one of those members due to be rotated off POPA, and had said my farewells to the APS staff at our last meeting in November. However, in our recent elections the FPS membership was kind enough to re-elect me for another term. I accordingly showed up again for the February meeting, to be greeted by a few raised eyebrows and suggestions that I had become “the permanent representative.” Regardless of this jocularly, I was grateful that I had prior knowledge of the workings of POPA and of the history of some of the continuing issues we face.

The most common sentiment among the old hands at POPA was a huge relief that the most contentious question that we had addressed was, at least for the time being, off the table. In November the APS Council had approved the Statement on Earth’s Changing Climate. This was the culmination of a project that had begun in 2013 with a discussion of whether to retain or rewrite the 2007 statement. Some will recall that the wording of that statement was considered “strong” at the time, and it soon became apparent that there was no shortage of POPA members eager to weaken it.

Early drafts of a proposed new statement focused fiercely on the inadequacies of existing climate science, reflecting a view later articulated by the then chair of the drafting subcommittee as “climate science is not settled”. As late as mid-2014, the draft statement on climate science led off with a ringing, retrograde call to battle, stating, “While there has been significant progress in climate science, serious deficiencies remain in our abilities to observe, understand, and project the climate.” It was an arduous struggle to move from this unfortunate starting point to the final product, which substitutes “challenges” for “deficiencies”, and wraps the aggression in an emollient coating, so that the relevant section now reads “As summarized in the 2013 report of the Intergovernmental Panel on Climate Change (IPCC), there continues to be significant progress in climate science. In particular, the connection between rising concentrations of atmospheric greenhouse gases and the increased warming of the global climate system is more compelling than ever. Nevertheless, as recognized by Working Group 1 of the IPCC, scientific challenges remain in our abilities to observe, interpret, and project climate changes.”

The overall final statement is, at best, unobjectionable. It is not the clarion call to action that some of us wanted, but it at least does no harm. Attempts to qualify our “call to support actions that will reduce the emissions of greenhouse gases” by insertion of the weasel word “prudent” in front of “actions” were narrowly beaten back. Our anodyne statement is now Hippocratic but no longer hypocritical.

Issues on the agenda for the coming year include a proposed study on the barriers women face in obtaining a degree in physics. Less formidable challenges include helium stewardship and the review of past APS statements on the use of nuclear weapons (thought to be a bad idea in 2006) and on the need for scientific review of the funding of research facilities (we were for it in 1991). The concern about “the possible use of nuclear weapons against non-nuclear-weapon states” that was widespread in the neo-con era of 2006 might seem to have abated in the following years. However, a leading contender for the U. S. presidency recently produced the utterance: “I don’t know if sand can glow in the dark, but we’re going to find out.” This suggests an attitude that goes far beyond the spirit of pure scientific investigation, and reminds us that renewal of our 2006 statement may be timely.

A more thorny issue may be a statement from 1996 on energy policy that is up for review. Those of us who are veterans of the climate wars, and still licking our wounds, approach this one with circumspection.

Philip Taylor
Case Western Reserve University

Statement approved by Council November 15:

https://www.aps.org/policy/statements/15_3.cfm

2007 Statement:

http://www.aps.org/policy/statements/07_1.cfm

Climate science is not settled:

<http://www.wsj.com/articles/climate-science-is-not-settled-1411143565>

Use of nuclear weapons:

http://www.aps.org/policy/statements/06_1.cfm

Review of facilities funding:

http://www.aps.org/policy/statements/91_5.cfm

Glow in the dark:

<https://www.youtube.com/watch?v=ydRyBAURKuc>

Energy policy:

http://www.aps.org/policy/statements/96_2.cfm

Science Agency Leaders Discuss “Future of U.S. Science”

Pushpa Bhat, Fermilab

President Obama’s Science Advisor Dr. John Holdren, the Undersecretary for Science and Energy Dr. Lynn Orr, National Science Foundation (NSF) Director Dr. France Córdoba, and NASA Administrator (Major General) Charles Bolden, spoke at a symposium on “Grand Visions for the Future of U.S. Science in a New Global Era”, at the annual meeting of the American Association for the Advancement of Science (AAAS) in Washington D.C., in February 2016. I had the pleasure and privilege of organizing and moderating the symposium.

Opening the session with introductions to this distinguished panel of speakers, I posed the central questions for the symposium in my introductory remarks – Where do we want to see science in the United States in the coming decades, and how do we realize those grand visions? The U.S. was a strong global leader in science and technology, innovation and entrepreneurship, for most of the previous century. But now, in these early decades of the 21st century, when other regions of the world are ramping up their investments in science substantially, federal investment in science in the U.S. has stagnated for more than a decade. Federal policies and actions taken over the next decade will determine the trajectory of U.S. science and its scientific leadership for decades to come. We anticipate astounding advances in science and technology in the next couple of decades, presenting tremendous opportunities for U.S. leadership and entrepreneurship. What strategic planning is needed to bolster U.S. science and to exploit the opportunities for the U.S. to lead global partnerships in scientific and technological pursuits to address humanity’s great challenges?

Holdren, who directs the White House Office of Science and Technology Policy (OSTP), presented the view from the White House and said that Science, Technology & Innovation (ST&I) are central to meeting key challenges of economic growth, healthcare, clean energy and national security, as well as to “lifting the human spirit through discovery, invention, and expanded understanding.” He further noted that the U.S. ST&I matters also because it is a magnet for ST&I talent from abroad, and international cooperation in ST&I, facilitated by domestic strength in these domains, helps build stable bilateral and multilateral relations and institutions.

Citing the many studies and reports over the past decade by the National Academies, the National Research Council, the President’s Council of Science & Technology Advisors (PCAST), and other organizations on the status of the U.S. research enterprise and recommendations for the path forward, Holdren emphasized that the Obama

administration has taken the advice of the ST&I community to an extraordinary degree, subject to constraints of budget. In his first inaugural address on January 20, 2009, the President had vowed to “restore science to its rightful place,” Holdren pointed out, and that in the Recovery Act of 2009 there was a boost of \$100B in the S&T budget, of which \$20B was for research. Holdren mentioned that the goal was to lift the total (public + private) R&D investment to $\geq 3\%$ but this goal which was on track in 2009-10, was disrupted by the spending caps in 2011-15 due to the Budget Control Act. Then he briefly discussed the R&D budgets from FY15 and FY16, and the President’s budget for FY17. He talked about a number of S&T priorities and initiatives under President Obama in the past seven years and argued that, with his “vision” for science, the President has also “charted a practical path and walked the walk”.

NSF Director Córdoba, spoke about the research programs at all scales of science that the NSF supports – the smallest scales studied through experimental particle physics to the cosmic scales in astronomy and astrophysics. She talked about many of the ground-based observatories and telescopes, about the discovery of gravitational waves (announced by the NSF-funded LIGO collaboration a day before this symposium), new cross-agency initiatives such as the Brain Initiative and the Food-Energy-Water Nexus, about global STEM education and increasing international partnerships.

Undersecretary Orr emphasized that fundamental scientific research is essential to our energy future, and that the Department of Energy (DOE) funds scientific research through ten National labs and three applied energy research labs. He talked about the neutrino science research at Fermilab and other basic science areas as well as exascale computing and its potential in simulations of complex systems and processes. He also talked about the Mission Innovation initiative launched by the President and 19 other world leaders with the goal of doubling the government investments in clean energy R&D over the next five years.

NASA Administrator Bolden made remarks on NASA’s ambitious program to send American astronauts to Mars in the 2030’s and to asteroids before then. “We are planning with a long view in mind,” Bolden said, “we have developed a stepping stone approach that builds success successively on our work, and is focused, affordable, and sustainable.” He talked about how NASA’s satellites are studying our own planet providing valuable and critical information, and on studies on the International Space Station that is becoming a great platform for earth observation



Future of U.S. Science panel at AAAS 2016 Meeting, February 12, 2016, Washington, DC.

in addition to being an amazing resource for researchers with experiments on board. He mentioned that NASA has about 700 international agreements with more than 120 countries, most of them in science collaborations. Bolden said that the future of NASA science is strong. It is helping to uncover the secrets of the universe and it is helping us to create the future and that, as President Obama said, “we are pushing farther into the solar system not just to visit but to stay.”

A panel discussion on how to build national consensus on adequate investments in science, globalism, and international partnerships, and Q&A with the audience followed.

In response to the question on how we build consensus across the political spectrum on the importance of science research and adequate investments, Holdren said that there is a strong bi-partisan consensus that recognizes the importance of basic science research, and also, for example, biomedical research. He said, however, that we have to work very hard to restore a sense of bipartisan consensus on some of the other important propositions of science. Bolden commented that the key is “engagement” with Congress, and finding common ground, finding allies on both sides of the aisle. Orr noted that there is good evidence that the S&T research has made fundamental contributions to the U.S. economy and has helped us lead the world, and given us the competitive edge. “In the energy transitions that are ahead, trillions of dollars are going to flow; as long as our technology basis is strong and scientific underpinnings are strong, we have every shot at being the leader.” Córdoba discussed how science is becoming entwined with our popular culture and how outside the beltway science is strongly supported by the public and that we need to bring that into the inside of the beltway.

In response to a question as to whether there is evidence that spending 3% of the GDP on R&D is the right amount, Holdren said that it is challenging to know how much is enough, but it has been disappointing that we have not reached the target of 3% for R&D investment in the U.S. and that there is clear empirical evidence that the current investment in S&T is inadequate. “NIH is able to fund only a third of the worthy projects,” Holdren said. If it were up to him, he said he would have spending be 4% of the GDP. Córdoba mentioned that the grant success rate at the NSF for early career investigators is “much much lower” and expressed concern that as a consequence we might be losing some very good people. Orr said that the grant application success at ARPA is only about 2%. Holdren hoped that since the research and experimentations tax credit has now been made simpler and permanent, more investment could come from the private sector and help us reach the 3% goal.

On international partnerships, all panelists agreed that there are plenty of international collaborations and cooperative agreements, and activities that are going amazingly well. Holdren’s summary on this topic was, “people from around the world want to do more together in a collaborative and cooperative way. It is quite extraordinary.”

The agenda and slides from the session can be viewed at <http://home.fnal.gov/~pushpa/aaas2016panel.html>

Pushpa Bhat, a senior scientist at Fermilab, is a former Chair of the Forum on Physics & Society and currently serves as the Forum Councilor. She is a Fellow of the American Physical Society and American Association for the Advancement of Science.

Gravitational Waves Ripple Through House Science Committee

Gregory Mack

Several comments during the House of Representatives Committee on Science, Space, and Technology's February 24 hearing on LIGO's tremendous gravitational wave discovery took me by surprise.

First, Committee Chairman Rep. Lamar Smith (R-TX) praised LIGO during his introductory remarks, saying "The NSF's support for the LIGO project is a great example of what we can achieve when we pursue breakthrough science that is in the national interest."

That last phrase surprised me.

Smith sponsored a bill that passed the House recently titled "Scientific Research in the National Interest Act" H.R. 3293. This legislation prescribes that NSF, whose mission is to support basic science research, only fund scientific activities if they fall into one of seven categories that the bill classifies as "in the national interest."

It's unclear he would have found the fundamental research done decades prior to the LIGO announcement "in the national interest" based on his definition.

During the 1970s and 1980s, NSF funded Rainer Weiss's initial investigations into laser interferometric techniques that ultimately formed the basis for LIGO, resulting in the construction of the NSF-funded facility in the 1990s. The investment paid off in a huge way with the confirmation of the final, big prediction of Einstein's General Relativity.

But would it have been funded if H.R. 3293 were in place? Would Smith deem Weiss's research a satisfactory fit for one of the categories?

The White House Office of Science and Technology Policy (OSTP) put out a comment in opposition to this bill. Along with noting that the NSF gold-standard merit review process already works to select the best proposals for federal investment, the OSTP document states that "most of the criteria offered by the bill for determining whether an award for basic research is in the national interest are not applicable to basic research at all—they relate to whether

the research will increase economic competitiveness, increase health and welfare, strengthen the national defense, and so on, and, thus, they are applicable only to applied research."

Although Smith said LIGO was an example of science "in the national interest," his first question to the witnesses after their statements asked about the discovery's practical applications. While I had expected this question from him, I hadn't expected it following the context of his opening statement. Was he separating "practical application" from "national interest" (which would seem at odds with the wording in the bill)? Was he asking how it fit in with his criteria?

Of course, as with many basic research discoveries, we don't know the answer to his question yet. In response, the witnesses discussed some important consequences stemming from the scientific processes used to reach this discovery. One aspect was innovation. To get the precision needed to measure a detection involving the size of one billionth of one billionth of a meter, technological advances had to be made. Another was workforce development. People had to handle the vast amounts of data generated by the experiment, resulting in many data science experts. A long list of companies was rattled off during the hearing where LIGO graduate students had found employment as data analysts when they finished their degrees. Yet another was education, a subject addressed by Reps. Elizabeth Esty, Suzanne Bonamici and Barbara Comstock. The LIGO team has developed education materials and programs to help with understanding this important discovery, and the science behind it, with a goal of informing and inspiring a diverse STEM workforce.

As the witnesses illustrated, all of these examples show the importance of supporting this type of research—it's not only about advancing scientific knowledge, but also the societal benefits and developments that come with the process. That certainly, by anyone's criteria, is in the national interest.

Lessons in Mixing Science and Policy

Christopher Spitzer

Readers of this newsletter will not be surprised to learn that there is a big world outside of academia, and that science plays a key role in addressing society's challenges in areas that range from climate change to data privacy. At the same time, effective approaches to these challenges demand political feasibility in addition to technical soundness. A good solution isn't worth much if no one agrees to implement it.

I became interested in the intersection of science and policy when I was a graduate student, at a time when there appeared to be a growing gap between the two. The question of implementation loomed large in my mind. I often heard discussion of the need for science to "inform" policy, but could find scant information on how this could actually be achieved in a meaningful way that improves outcomes from the political process. Moreover, as a physicist whose background was in particle theory, it wasn't clear what I would be able to contribute. My knowledge of cosmology and hypothesized extensions of the standard model did not appear immediately applicable to, say, the problems of encouraging energy efficiency in the United States or building a stable society in Afghanistan.

Yet, within a few years of receiving my Ph.D., I found myself staffing a US senator during Energy Committee hearings, and, shortly afterward, riding in the back of an armored SUV traveling through the streets of Kabul.

A pair of remarkable programs enabled this transformation. The 2010-2011 AIP Congressional Science Fellowship (APS has a closely related program) provided my first glimpse behind the scenes of the political arena. In that position I worked with the legislative team in Senator Jeanne Shaheen's personal office, covering science, energy, and the environment. From there I moved to a AAAS Science and Technology Policy Fellowship at the State Department from 2011-2013. I was on the Afghanistan desk (which means office, in State's lingo), covering economic development with a focus on energy, education, science, the environment, and health. Both fellowship programs offer a path for scientists to go beyond simply learning from afar how the federal government functions. They provide a chance to become part of the government, while engaging some of the toughest problems we face. It's science policy in practice, not theory.

These fellowships acted as a boot camp in science policy that not only answered my question about implementation and helped me develop skill in translating between science and society, but also offered a number of lessons, not to mention a few surprises, about what it's like to work in the world of policy and politics. Here are a few that stood out:

Science Matters: Despite the frequent rancor visible on television, I found that science and rigorous analysis play a

central role in the conduct of government. While I was in the Congressional office, during discussion with staff on both sides of the aisle, science remained one of the few "honest brokers" of information. While this didn't always translate to speeches on the Senate floor, I found it possible to quietly advance scientifically sound policy prescriptions.

Abilities Transfer: As I anticipated, at no point in my fellowships did I make use of my knowledge of the Higgs boson. What I did not expect is that the core skills and abilities I had developed as a physicist—abilities I previously took for granted—were highly valued by the offices in which I worked. These included rapidly understanding complex information, assimilating disparate data, conceiving of novel solutions, and offering good judgment. While these are a scientist's bread and butter, most policy staff feel uncomfortable applying them in technical areas, and are happy to have someone on their side who is willing to grapple with them. Outside of the technical agencies, many scientists who work in policy must be generalists, and I wasn't an expert in the fields included in my portfolios. However, I found my training was sufficient to understand enough to develop appropriate policy prescriptions. In short, scientists have a lot to offer in government despite not having the educational background or experiences of many who serve as legislative or executive staff.

Relationships Dominate: Public policy is built on relationships rather than ideas. Politicians and senior decision makers know that they lack the background to understand all aspects of the issues for which they're responsible. However, they do have skill in judging character. A recommendation from someone they trust is worth much more than any well-written whitepaper or policy brief. Developing trust, say between a scientist and a Congressional office, can take years of frequent contact. While occasional events like Congressional Visit Days may provide a quick boost in awareness among policy staff, it is the continuous long-term involvement that really helps push policy forward.

Narrative is Key: Politicians and other policy makers have specific constituencies to which they must be responsive. There are a lot of good policy ideas, but the ones that take root are those in which the decision makers understand why their constituents would benefit. A clear, compelling narrative is the way to achieve this—that is, a good story that links the policy to a beneficial outcome. Moreover, the most influential communicators are those who understand how a Congressional office or federal agency works, and deliver the narrative in a form that fits into the workflow. A succinct summary and specific recommendations are much more useful than a long report or generalizations.

Patience Pays Off: Real shifts in policy are not usually

achieved overnight. During my time in Congress, I worked on an energy efficiency bill that was introduced in 2011, and was built on a lot of good ideas that had been previously discussed in the Senate. That bill was not passed that year or the next. Instead, a series of staffers, including subsequent Congressional Fellows, repeatedly refined and re-introduced the bill until finally, in 2015, it was passed and signed into law. This process of long-term results guided by many hands is typical.

While every physicist has the underlying ability to become effective in influencing policy, there is a shortage of those who actively find ways to engage. Despite the potential for benefit to the field, it's not something that's typically encouraged by graduate school or the tenure system. For those who have interest and are willing to step out of the comfort zone of research, becoming involved in policy has enormous benefits both for the individual and to the field.

Christopher Spitzer
UC Research Initiatives
University of California, Office of the President

A Slightly Random Walk from Physics to Policy and Beyond

Marcus Extavour

INTRODUCTION

I was writing my PhD thesis and preparing for a defense when I first told my advisor that I was considering a jump into the science policy world. He said, "Interesting. Go for it!" Looking back with the hindsight of a few years, I am so grateful for that support at a sensitive moment in life and career. Those conversations could easily have gone another way, taking on a different tone that is often present in our scientific communities: that a move away of academia is the end of all good career prospects; that there is nothing of substance to be achieved for a scientist in politics and policy; or worse still, that engaging the realm of policy and politics risks undermining that most precious asset of the scientist, credibility.

In my own experience, the migration from the lab to the science policy world has been enriching, challenging and fun. But the transition has also been tortuous, and not without frustration, terror, and apathy to offset the excitement and sense of mission and purpose that policy work can offer. And I know that my experience is not unique. I think much of the shared experience in the move from academic or bench science to policy-oriented problems is directly related to the cultural and philosophical differences between the two worlds. As physicists, the way we think about problems, frame solutions, interact with peers, and even define evidence are all very different than the methods of our cousins in law, economics, politics, and business – the dominant players in public policy, even science policy!

WHAT IS SCIENCE POLICY?

First, a bit of background on what I mean by "science policy." I think about the problems of science policy as be-

longing to one of two categories: "policy for science," and "science for policy." This is not an original thought, but the distinction is helpful for putting some common conceptions about science policy into a more nuanced context.

Policy for Science. Policy for science is the exercise of planning, managing, supporting, and optimizing the scientific activities of an organization, region, or nation. How to design and run the funding agencies and their associated grant programs? How to manage and fund fellowships for students and early-career scientists? And at the political level, how to allocate resources among the universe of scientific pursuits, from basic R&D, to applied or commercialization efforts in domains ranging from clinical medicine, to ecology, to astronomy. How to even define these pursuits? Invariably this branch of science policy can be dominated by budget questions, specifically their size, their time derivatives, and their managers.

I think this is the most common notion of science policy among physicists – it certainly was mine. And I think it's fair to say that lab budgeting and grant program structures are possibly the least motivating subject for most physicists. They're in it for the science, not the accounting.

Budgets and funding for science are clearly a crucial matter, so I won't bother trying to rationalize this side of science policy. Just think about what the relative increases or decreases in NSF program spending, or any other relevant funding body, have meant to your own work and career. Hammering out budgets may not be for everyone, but I think we're all glad someone is working on it.

Science for Policy. In my case, the kernel of interest in science policy really blossomed when I became aware of

the second category: science for policy. Science for policy is the exercise of using scientific approaches, data, and understanding to inform and support public decision-making. “Evidence-based decision making” might be the best current hallmark phrase of this activity.

If Not Us, Then Who? Many systems of government have a long history of incorporating science directly into public policy, most notably in defense and the regulation of food and agriculture. But today, a growing number of pressing public policy questions involve science, technology, or engineering at their core, for instance: climate change and energy systems; digital and cybersecurity rights and privacy; ecological conservation; artificial intelligence; synthetic biology and reproductive rights. These areas all present incredibly complex public policy questions, but are firmly rooted in the science and technology of the 20th and 21st centuries. Physicists and scientists in general have a role to play to help our decision makers “Get the science right.” If not us, then who? But even more than a simple lesson on the difference between electrons and photons, RNA and DNA, or supplying data, maximizing the public good in tackling these problems calls for skill and approach to problem solving that is unique to physics and the other maths and sciences, to complement those already at the table from economics, law, business, and politics.

THEORY OF CHANGE – THE LINEAR MODEL

After discovering and understanding my interest in science and policy, the personal question became “now what?” How to get there from here? For me this was largely a process of trial and error, seeking mentors and feedback, and repeating. I describe it here in two ways, in hopes that it might offer guidance (or cautionary tales) to others of a similar mind, or at the very least to spark a good conversation.

I call the following description of my career the linear model for two reasons. First, it’s a straightforward chronological description of the steps (and mis-steps) I have taken, akin to a typical academic CV. Second, like most linear models, it has its uses, but misses much nuance which can be critical to deeper understanding.

Even as I pursued my experimental work in quantum optics and atomic physics as a graduate student in the Department of Physics at the University of Toronto, I began to more seriously explore careers in law, education, and politics. Mostly dabbling, and mostly out of curiosity and interest. I have always loved math and science and being creative with my hands in the lab, but I also loved teaching and science outreach and finding ways to connect science with the rest of my life. Without this basic feeling, I decided to seek spaces where a physicist could work on broader problems than those I had explored to date.

As I wrapped up my PhD work I began volunteering with the Canadian Science Policy Conference – at the time a grassroots organization of postdocs, students, and young professionals trying to pull together a critical mass of Canadian science policy geeks. This expanded my network outside of academic physics, and helped me begin to understand how professional scientists can and do fit into broader policy structures. After completing my PhD, I took a left turn by leaving academia and working as a quantitative analyst at a power utility, where I wrote code to analyze electricity markets. This was my formal introduction to the energy world, which remains my focus today. Energy, science and policy came together for me as a AAAS Science & Technology policy fellow, during which, with generous support of the SPIE / OSA Guenther Fellowship, I took up a position on staff of the U.S. Senate Energy & Natural Resources Committee in Washington, DC. Later on, back in Canada, I worked as a science policy consultant with the Council of Canadian Academies, and in fundraising and strategy of university / industry research partnerships in the Faculty of Applied Science & Engineering at the University of Toronto. Today, I manage the technical and operational aspects of global energy competition in CO2 conversion at XPRIZE (the NRG COSIA Carbon XPRIZE). The common threads of this linear model are physical science, energy technology and policy, government and industry interactions, and trying new things.

NETWORK EFFECTS

Like most academic CVs, the above description is simple retrospective narrative milestones, highlights, and formal education foundations. With a small number of exceptions, it is useless in practice for anyone other than its author who is trying to understand how and why and other subtleties of a move from physics to policy, and anything in between. So here is another description of my experience through and between these two worlds, which I jokingly call the “network model” because of it’s focus on interactions and skills learned and refined, rather than place and institution and title.

Physics meets policy, regulation, and governance. As an engineering and later physics student, I was well trained in the fundamentals of optics, atomic physics, materials science, and quantum mechanics. As my interest in energy grew, I realized that while I could do a great job explaining the thermodynamics of a power plant, or the optoelectronics of a photovoltaic cell, I had little or no practical understanding of the business, regulation, and operation of real energy systems. My odd decision to dive into work at a power utility (a culture shock in many ways, coming directly from academic experimental physics) was an attempt to fill in this blind spot. In exchange for technical depth, I developed breadth of understanding. Using technical tools (statistics, programming,

data analysis) I worked on financial and business problems in a heavily regulated industry. For better and worse, I also got a taste of the 9-to-5 cubicle lifestyle.

Elevator pitches. As a Fellow in Washington, DC, I had a great opportunity to work on my networking, writing, and presentation skills, both formally and interpersonally. Networking can be a dirty word for scientists, but for me the exercise of networking has been a challenge to (a) meet new people in rapid succession and learn how not to seem like a freak scientist (b) describe my interests and projects in direct, concise ways, and communicate passion for my work in a way that (hopefully) makes my conversation partner want to keep chatting, rather than politely head for the bar, and (c) understand what other people from backgrounds and professional traditions wildly different from mine, are working on, how they see problems, and what they find interesting. As a gross oversimplification, physicists tend to elevate content, knowledge, and subject matter above all else, while our counterparts in policy, economics, business, etc. place a much higher premium on interpersonal relationships. It's a hard habit to break; I still get funny looks every time I let slip "If we assume a spherical..." or "From first principles it seems obvious that...". But refining my skills and learning to navigate this world—in conversation, oral presentation, or written communication—often through trial and error, was and continues to be a valuable resource for me.

Follow the money. Finally, I point to my work in university fundraising, politics, and government consulting for helping me to understand money. By that I mean first gaining financial and economic literacy. Next, understanding the role of financial decision making and market forces in our basic research and funding frameworks, but also in broader policy conversations in science and related policy arenas.

In my lab career, as a graduate student and in industry, money essentially did not exist. This is a crazy thing to say, so let me explain. Money was never the driving force in daily lab routines, decision-making, and planning scientific work in the way that is in many other professions and aspects of life. I realize that my position as a junior scientist and not a group leader was privileged (any PI reading this is probably rolling their eyes in between grant applications and review committee work), but from my perspective it was always about the science.

How to define the problem; what tools exist at our disposal for approaching solutions; experimental design, data collection, and analysis; understanding and presenting our progress to the broader community in clear and compelling ways. In my work outside of academia, in an equally simplistic view, it's all about the money; discussion about problems, solutions, execution and efficacy are always immediately filtered through the lens of costs, affordability, rates of return, and

fiscal management. By this I mean that economics and finance play a vital, immediate role in these conversations—and, in my view, they should in any discussion of public good and public resources—in a way that they simply did not in my experience in the lab.

For me that meant building at least a basic facility with the language of economics, finance, and budgeting in order to develop credibility among my peers and mentors. It helps that I have a natural interest in these topics. But learning this new language, like any new language, opened entirely new horizons and opportunities to engage. In science, technology and innovation policy in particular, an understanding of market forces in technology development, investor types and priorities (grants, philanthropy, angel and venture investors, institutional investors), budgets for basic research, university finances, government budget pressures, etc., is extremely helpful when discussing how best to support scientific communities, and use science to inform public discourse.

A DC mentor once said that "Politics is about who gets what"; in other words, decision-making in a zero-sum scenario. This dimension in no way should minimize the importance of purely scientific and technical input and wisdom, but instead can enrich and sharpen the communications and impact of our community's voice.

CULTURE EATS STRATEGY FOR BREAKFAST

I wrote earlier that my personal transition away from lab-based science and into policy and beyond has been difficult and can be a personal challenge. So why encourage this transition for those interested, and how to think about this migration? It is easy to write and talk about, but often difficult to accomplish. One reason is that the marked differences in style, personality, and approach between physicists and typical policy wonks can make person-to-person and institution-to-institution communication and cooperation difficult. These cultural gaps are clearly surmountable, but I close by noting them here because they have been key learnings for me along my path from the physics research to science policy work, and could be helpful for others curious about the transition.

Evidence and Judgment. If science is about truth, then imagine the shock for a scientist at approaching and discerning truth using means completely outside the scientific method. On one hand, we scientists collect data, look for patterns, form hypotheses, test, refine, repeat. Data and evidence are central, predictive power trumps past results (if demonstrated to be incorrect) and the role of individual actors is less important than that of the group of scientists past and present that make up the field. On the other hand, public policy and government decision making in liberal democracies has more in common with legal thinking than with the scientific method. To use another oversimplification, judgment and reason in law and policy trump data and evidence as methods for establishing

facts and making decisions. Whereas scientists are conditioned to think of truths as absolute and objectively discernable using data and experiments, the legal influence on policy makers leads them to favor truths established through argument and reason, and decisions made by informed, wise individuals or small groups who consider many arguments.

Think of a courtroom. Defense attorneys may call an expert witness to testify on technical subject matter. Prosecution attorneys may call a separate expert witness. Neither witness is considered a fully reliable source of objective, unbiased technical information. Rather than an experiment to test one idea or explanation against another, as a scientist might suggest, courts use judges and juries who listen to both sides and make a decision using judgment.

This cartoon example of legal decision making is reflected in many high-profile public decisions. In my time in the US Senate, I observed the way my boss, the Senator, would accept advice from legal, economic, scientific, political, and social experts, and make a decision according to his own judgment and principles after considering all arguments. (I considered myself lucky to work in such an idealized environment most days, since decision making can be much less reasoned and much more biased.)

This approach can be difficult for scientists to understand or appreciate since we are used to thinking of scientific truths as THE truths. After all, the scientific method is a system of weeding out false theories, and then subjecting truths established by this method to continuous and open challenge in the face of new data. In my view, this culture clash informs part of the current thrust for “evidence based decision making” that is often advocated by scientific and other technical communities. In the best cases, this call for transparency and consideration of reliable evidence is proper and indispensable. But in its worst manifestations, it can degenerate into pleas to “do it my way” or “cite my work” and a failure to appreciate that legal, social, or political considerations can be just as important or even more important to a given policy question, even in the face of robust and clear scientific evidence.

Tell Me a Story. Another common culture clash centers on the role of individual and personal narratives in science, versus their place in the policy world. In science, while we celebrate and lionize singular genius, we generally understate the impact of individual contributions. We write papers using passive voice. Objectivity demands dispassion. And in a very practical way, science is a team sport - in local collaboration on individual projects, but also because each addition to knowledge and understanding necessarily builds on and incorporates the work of others.

To be crass, nobody ever won an election by minimizing their contributions and being self-deprecating. This is not a statement of personal preference, or meant to be an “us versus them” analysis. Rather, it’s a recognition that different communities place different value on the style and role of personal narratives in accomplishing their goals.

The ongoing U.S. Presidential election cycle is a great example. In some shape or form, each candidate defines and articulates their own personal narrative, including an origin story, a career arc, motivating passions, and sense of purpose. Political strategists and pundits routinely use words like “narrative”, “discourse”, “character”, and “values”. Figures such as Ronald Reagan “the great communicator”, and Bill Clinton “the great explainer” are celebrated for these qualities.

Electoral politics are different from policy making, and presidential politics are an even more extreme example. Still, the point is that a world influenced (if not dominated by) the power of personal narratives can be an uncomfortable one for those at home in scientific traditions. This is especially true on a personal, day-to-day level. In my case, I realized that I would sometimes understate my experience, skills, and abilities. Scientists are famous for declining to comment on issues outside of their direct, specific area of focus, even though in relative terms among peers in policy, they may very well be “experts” in those other areas. Of course over-reach and exaggeration are the other facets of this issue, but understanding the risks on all sides and broadening my actual expertise has made me a more effective team member and leader.

It’s fair to say that the physics community is not known for its storytelling. That may be changing somewhat, with recent productions such as *Interstellar*, *Cosmos: A Space-time Odyssey*, *Particle Fever*, and even the recent gravity waves announcement from LIGO, each tackling the physics storytelling challenge head-on. But for me, learning how to describe my work without shying away from my personal motivations, feelings, trails and tribulations – in other words, incorporating elements of classic storytelling – has helped me to get my better ideas across in a world of non-scientists.

CLOSE

A life in physics and science policy and the journey in between is not for everyone, but for me it continues to be a happy blend of my science brain and my desire to have broad impact and create positive change. Idealistic? Definitely. But if I’m honest, idealism is what attracted me to science in the first place, and still does.

Marcus Extavour
Director of Technical Operations, Energy & Environment, XPRIZE

Fukushima Today: A First-Person Account from the Field and the Conference Table

Subrata Ghoshroy

It has been more than four years since the east coast of Japan was hit with a trifecta: an earthquake of Magnitude 9 on the Richter scale, followed by a massive tsunami triggered by the quake's tremors, and then the meltdown of three nuclear reactors in the Fukushima Daiichi nuclear generating complex. Design mistakes, a poor safety culture, and human error exacerbated the situation. And it all happened within the span of an hour, searing the name "Fukushima" into the collective memory of all. Like Hiroshima a few hundred kilometers to the south, the name Fukushima became synonymous with the horrors that can befall a nation from uncontrolled atomic chain reactions.

I had traveled to Japan to attend a meeting of the Japan Scientists' Association in Yokohama, near Tokyo, which was expected to announce a major change in its pro-nuclear energy position.

While there, several other conference attendees and I received permission to go on a guided tour to the restricted areas surrounding the Fukushima Daiichi plant to see for ourselves, first-hand, the things that we had all been discussing in conference rooms and lecture halls for the past three days. One of the conference organizers—Yoshimi Miyake, a professor at Akita University—accompanied us on our trip to Fukushima. (To be precise, Fukushima is a prefecture with the namesake city its capital. The plant itself is called Fukushima Daiichi.) Another participant, Lucas Wirl from Germany, volunteered to act as our photographer.

What follows are my personal impressions from the tour that occurred immediately after the meeting, and a few of the relevant highlights from the meeting itself—which called for the elimination of nuclear power from Japan as soon as possible. A total of seven of us traveled about 50 miles, starting from a point some 40 miles south of the power plant, then heading along a series of coastal highways until the road took us to within just a little over a mile and a half from the plant, within the town limits of Futaba—which was about as close as anyone could get to the site without special protective gear. We then continued northeast to the village of Namie, one of the nearest villages to the plant, and a place where the government was aggressively pushing for former inhabitants to return to live year-round.

Along the way, we passed through many towns and little villages that had been hit hard. As for the plant itself, the radiation levels are so high that it is difficult to even operate robots. And in places like Namie—whose closest boundary lay less than five miles away from the plant—the radiation levels posed significant risks, because they are

so much higher than normal natural background radiation. Also accompanying us were Itoh Tatsuya of the Iwaki City chamber of commerce and Baba Isao, an assemblyman from the town of Namie—both locales hurt substantially by the multiple disasters.

Getting there. We traveled by express train from Tokyo to Iwaki City in Fukushima prefecture, where we stayed overnight before beginning our journey the next day. As we left our hotel after breakfast, one of our guides—Tatsuya—readied his Geiger counter. Before leaving, he took a measurement of the background radiation level and announced that it was higher than normal today, even though Iwaki is more than 40 miles from the ill-fated power plant. It sounded like he was a weather forecaster talking about humidity levels. He did not give a figure as to how much higher the background radiation was.

As we started heading north, we saw homes destroyed by the tsunami. Iwaki lost 200 people, Tatsuya said. As we began to reach the outskirts of Iwaki City, the radiation level rose consistently, if in very small amounts. Here at about 20 miles from the plant it was about 0.1 microSieverts per hour—objectively not really high at all, but above where we started, and marginally higher than the normal natural background radiation. The Geiger counter's needle flickered, occasionally registering higher levels, especially when we passed through some tunnels.

As I looked out the window, I thought of what one of the conference presenters, Mitsugu Yoneda of Chuo University in Tokyo, had said: There were 120,000 evacuees across the Fukushima prefecture, and it was unlikely that they would be able to return to their homes in 2016 in the so-called "difficult-to-return" zones, where the cumulative annual exposure is expected to be 20 milliSieverts or more. In recognition of this fact, the government had come up with a new category called "release preparation zones," where the cumulative annual exposure is estimated to be well above "normal" but less than 20 milliSieverts. The government's plan to promote an early return to these areas was called a politically motivated whitewash by Yoneda, because anything close to 20 milliSieverts is far higher than the normally accepted safe annual limit. (One milliSievert is about equal to about 100 millirems—the units most commonly used in the United States. Thus, 20 milliSieverts would be 2,000 millirems.)

Different countries have different standards, but in the United States, the Nuclear Regulatory Commission requires that its licensees limit annual radiation exposure to individual members of the public to 1 milliSievert (100

millirems) above the average annual background radiation. Because the natural background radiation usually averages in the range of about 3.1 milliSieverts (310 millirems), that figure plus the allowed exposure from the nuclear power plants makes for a total of about 4.1 milliSieverts (410 millirems) annually—a far cry from the 20 milliSieverts (2,000 millirems) that could be encountered by a member of the public in any putative “release preparation zone” near Fukushima Daiichi.

To give a sense of scale, the average person gets 0.04 milliSieverts (about 4 millirems) from a single chest X-ray, and about 0.24 milliSieverts (24 millirems) in cosmic radiation annually if that person is living at sea level. Cumulative dosages of 500 milliSieverts (50,000 millirems) or above are considered “high,” and cause acute radiation sickness, many different forms of cancer, and death. But because radiation affects different people in different ways—depending upon one’s age, general health, and genetic predisposition—it is not possible to indicate precisely what dose is needed to be fatal to a given individual. All that researchers can do is give statistical averages, such as “50 percent of a population would die within 30 days of receiving a dose of between 350,000 to 500,000 millirems (3,500 to 5,000 milliSieverts).”

Some of the other background information that Yoneda provided was similarly dismal. For one thing, the building containing the failed reactors has radiation levels as high as 4,000 to 5,000 milliSieverts per hour (400,000 to 500,000 millirems per hour), making even the operation of robots difficult. In fact, two power company robots had to be abandoned while inside the depths of the plant. And some spots, such as inside the primary containment vessel, went as high as 9.7 Sieverts per hour (970,000 millirems per hour). In addition, it has not been possible to precisely locate the melted core. (Another conference speaker, Jun Tateno, who was a former research scientist with the Japanese Atomic Energy Research Institute, accused the government of suppressing voices from the scientific community that were critical of the safety of power plants. He said that we have reached a situation in which we do not even know how much plutonium is in the core.) In the meantime, huge amounts of water must be pumped in to keep the reactors cool; this liquid then mixes with ground water, contaminating it as a result.

The picture is not much better when it comes to the land. In an effort to decontaminate residential areas, radioactive soil is being dug up from approximately 1,000 sites. The government wants to consolidate this contaminated material in semi-permanent storage sites in the “difficult-to-return zones” in Futaba and Okuma towns. Local residents, meanwhile, fear that these could turn into permanent repositories of radioactive material.

I was jolted out of my reverie by the comments of

Tatsuya, who pointed out a large apartment building that looked empty. He said that in days past there would have been many children’s clothes hanging from the balconies. The only people who are living there now are some of the laborers who are working to decontaminate the town.

Our first stop was J-Village, about 18 miles from the plant. It housed a huge sports facility, including what was once Japan’s largest soccer-training complex. Because of its stadium, many of Japan’s top players once trained there. Now abandoned, the stadium was overgrown with weeds, and the scoreboard still carried the results of the last game. The parking lot was full, but not with the cars of soccer fans. The vehicles belonged to the decontamination workers who were taken by buses from there to the restricted sites.

Tatsuya noted that the Geiger counter was reading about 1 microSievert per hour as he moved the counter around the parking lot. That was bad enough; it translated to 8.76 milliSieverts per year.

He then bent down to take a reading from a grassy spot. The counter needle pinned to the right. “Off the scale!” he exclaimed. It was higher than 5 microSieverts per hour, which is more than 50 times higher than normal natural background radiation per hour in Tokyo. It translated into a cumulative annual dose of 43 milliSieverts—many times above the 6.2 milliSieverts (620 millirems) average annual exposure for members of the general public, according to the US Nuclear Regulatory Commission. (In addition to the natural background radiation level of about 3.1 milliSieverts [310 millirems], the average person is also likely to fly in an airplane, watch television, or undergo medical procedures, and all these manmade sources together add another 3.1 milliSieverts [310 millirems] per year to one’s exposure, making for a total radiation dose of 6.2 milliSieverts, or 620 millirems. This figure could colloquially be considered the “normal” amount of radiation exposure for a member of the general public, as a very rough rule of thumb.)

We left soon thereafter. We were told that most workers did not wear dosimeters to record their cumulative radiation dose. There was good money to be made in decontamination work. They did not want to know.

But if one does the math, what the workers and their supervisors were ignoring—or were being told to ignore—could be significant. If a person spent one week working at this part of a supposedly safe parking area for 8 hours per day, then he or she would have been exposed to 40 microSieverts per day. And if that person was there for a 5-day workweek, then over the course of a single week that person would have been exposed to 200 microSieverts. In a year, that person could receive 10 milliSieverts, a significant dose. Of course, scientists are rightly cautious of such “anecdotal” evidence; our Geiger counter readings could have been off, or the machine calibrated incorrectly,

or some other source of error introduced—though I doubt it because it had earlier read the background correctly. But the result of such quick and dirty, back-of-the-envelope calculations for what is supposedly a low-risk parking area, well away from the restricted hot zones, do give one pause—especially as the ongoing lack of dosimeters means that no one really knows a given individual’s cumulative dose. The amount of exposure to a thing that you cannot see, hear, smell, taste, or feel sneaks up on you. Even when you think you are safe, you are not.

If nothing else, the fact that a simple, random spot-check registered so highly is an eye-opener, and counter to what has been officially portrayed. An April 16, 2015 story in the *Asahi Shimbun*—one of the major, reputable, national newspapers in Japan, of a stature comparable to the *New York Times*—quoted a government agency as saying: “Cleanup crews around the crippled Fukushima No. 1 nuclear power plant were exposed to an average dose of 0.5 millisievert of radiation per year, well below the government safety standard, a report shows.”

An important item seemed to lie further down in the article, which noted: “However, the health ministry said the number of workers surveyed is different from the total number of cleanup personnel reported by the Environment Ministry, which could mean the association failed to record radiation doses of all individuals working around the Fukushima plant.”

No wonder there has been public distrust and charges of a lack of clarity about the radiation clean-up operation, as can be seen in the title of a 2013 *Guardian* newspaper article: “Life as a Fukushima clean-up worker—radiation, exhaustion, public criticism.” Even when the approximately 7,000 workers involved in the clean-up do wear dosimeters, that is no guarantee of accuracy; there have been reports of a Tokyo Electric Power Company executive who tried to force clean-up workers to manipulate dosimeter readings to artificially low levels by covering their devices with lead shields.

The voice of science. Because of such activities, it is hard to pin down basic data. Accordingly, the conference had been a key opportunity for researchers from different countries and different fields—including physicists, of course, but also economists and climate scientists, among others—to get together and compare notes.

Nearly 80 scientists, engineers, and academics from all over Japan attended. Many of the Japanese attendees were renowned academics in nuclear physics and engineering. Several had held high-level positions in the nuclear research establishment. Among international participants were delegates from the United States, Germany, and South Korea, among other places.

While there were no representatives from China at the meeting, Jusen Asuka, an environmental policy professor

from Tohoku University, gave his analysis of the impact of Fukushima on the Chinese nuclear program. He said that the accident in Fukushima created a figurative, as well as literal, shock wave throughout China: People started stocking up on iodized salt, and stores ran out of the substance within 30 minutes of opening. The Chinese government suspended all license applications for new reactors, temporarily halted all nuclear plant construction, and established a nuclear safety law. China also began investing heavily in non-hydro renewables.

The meeting’s goals. The importance of the meeting could hardly be underestimated, given that Japan is at a critical juncture in its debate about what path to follow in its energy future. On the one hand, a conservative government led by Prime Minister Shinzo Abe and backed by powerful forces in business and the nuclear industry, was pushing hard to bring back the nuclear plants—and even build new ones. Simply put, the Abe administration’s objective is to make the Fukushima Daiichi tragedy a thing of the past; therefore, it promotes the idea that things are getting back to normal. After all, Abe won an election victory in December 2014, with one plank being that the nuclear plants would be restarted. Abe is counting on the fact that with 54 nuclear reactors in a small country, many people’s livelihoods depended on the reactors’ continued operation.

It is hard to tell if the government’s promotional campaign is succeeding. The Abe government is continuing to push for the revival of nuclear power in Japan, as exemplified by the recent restart of the Sendai plant.

By doing so, it clearly sought to lay down a marker—and also perhaps to gauge public opinion before proceeding to restart other plants.

On the other hand, public opinion has been growing stronger in opposition—although the opinion polls have not been overwhelming. One of the significant aspects of the conference was the vigorous participation of women scientists like Miyake, who spoke out strongly against nuclear power and also challenged the male domination in the scientific community. Young mothers were participating in increasing numbers in anti-nuclear protests in Japan and also in Korea, we were told by Hye-Jeong Kim, a leader of the anti-nuclear movement in South Korea, who is also a member of the country’s Nuclear Safety and Security Commission, an equivalent of the NRC in the United States.

With these developments in mind, a scientific community that can speak with one voice and make a credible case against the government-industry publicity campaign is crucial. The Japanese Scientists’ Association envisioned its role as accurately communicating to people around the world the dangers of nuclear power and the seriousness of the damage suffered by the Japanese people. And the group hoped to use science to counter the forces that promote

nuclear power in Japan, and demand that Japan give top priority to renewables.

A welcoming banner. Heading north towards Tomioka, we found large tracts of land piled high with green trash bags. From a distance, the piles looked like vegetation; it was only as we got closer that we saw that they were full of the radioactive dirt that had been excavated from the topsoil as part of the government's efforts to decontaminate the soil. It appeared to be a hopeless task.

In reaching Tomioka—badly hit by the tsunami—we found a nearly destroyed town invoking an image of the Apocalypse. All we saw were homes, businesses, and shops as they stood or fell after the tsunami hit and then the radiation struck. There was no sign of life other than decontamination workers going about their grim task.

Continuing our journey toward Namie—one of the worst-hit towns, whose boundaries lie about six miles northeast of Fukushima Daiichi at the closest point—we passed through the small villages of Okuma and then Futaba. We continued onward, and edged as close as 1.5 miles from the plant at one spot, but no closer. All roads to the plant from here on were barricaded. Ironically, one banner welcoming visitors to the town read: “Nuclear Power is Our Future.”

Can Japan make the switch to renewables? A key goal of the conference was the public announcement that the Japan Scientists' Association formally opposed nuclear power in Japan, and that its opposition was based upon scientific analysis of the accident in Fukushima and its impact. This about-face was a major step; it meant that some of the same Japanese scientists who had been the most forceful and outspoken proponents of nuclear energy now opposed it. To bolster the impact of this statement, the association had to show both the economic and technical feasibility of alternative sources of energy. Consequently, much of the meeting focused on the lessons learned from the experiences of other countries, and the keynote speaker of the conference, professor Juergen Scheffran of Hamburg University, Germany, gave the European perspective on the implications of the transition from fossil and nuclear to renewable energy. The focus was especially on Germany, which is in the middle of its own planned transition to a non-nuclear future.

With that in mind, Reiner Braun, co-president of the International Peace Bureau in Geneva, Switzerland, spoke about the status of the German exit from nuclear power and entrance into renewables. Known as *Energiewende* in German (literally “energy turn”), it would entail shutting down all nuclear plants by 2022, with seven plants shut down immediately. The renewable energy sector would be expanded at the same time that there was a step-by-step

reduction in fossil fuel use; modern natural gas plants are to be used as a transition technology. Structural changes would also be made to the distribution network to account for the decentralized nature of the new energy supply.

Braun, a veteran of the protest movements against nuclear weapons and nuclear power, said it was important to understand why a politically conservative government had made this U-turn. A vast majority of the German people had rejected nuclear energy and there were decades of organized resistance, starting with massive protests against the stationing of NATO's tactical weapons on German soil. While progress was promising so far, Braun reminded his audience that *Energiewende* was the “largest technological challenge” faced by the country since the post-WW II reconstruction efforts. The political challenges, meanwhile, were comparable to those encountered after the reunification of the two Germanys after the end of the Cold War.

But there was no doubt it had to be done, or that Japan could learn from observing the German experience. The feeling from the meeting was best summed up by the conference chair, Tsuyoshi Kawasaki, an expert on climate science and an emeritus professor at Tohoku University. Kawasaki ended his brief remarks with the words: “The Japanese Scientists' Association believes that human beings and nuclear power cannot coexist.”

I was reminded of these words many times as we toured the forbidden land of once-lively towns of Fukushima prefecture.

It might have been worse. Finally we arrived at Namie, our destination, and as close as we could get to the actual plant itself. Another of our guides, Baba Isao, an Assemblyman from the town, had secured special permission for us to enter. We first went to the town hall for a quick lunch; the building had undergone a decontamination operation and there were a few town employees at work. A radiation level monitor with a large digital readout was in front of the building.

Namie had a population of 21,000 before it was evacuated. About 14,000 were relocated within Fukushima prefecture (his family being one) and 6,000 outside. Two hundred people were known to have perished in the tsunami. Isao told us that his wife had gone back to their house a few weeks ago and found the radiation level to be 34 microSieverts per hour, which is nearly 7 times higher than the “hotspot” we had encountered in J-Village. It would be considered an absolute no-go. Newspaper reports have cited other such hotspots in Namie.

Isao said that some people wanted to return, but he had advised them against it, although we found a convenience store to be open. Meanwhile, the government was making Namie's clean-up a priority, undertaking infrastructure improvement and house-to-house decontamination. The

town was considering a proposal that would allow people to return in 2017, but Isao was doubtful.

In addition to the presence of radiation, there was another reason not to return: There were no longer any jobs in these communities, where the nuclear power plant was the *raison d'être* for the town. In fact, before the accident, in a bid to boost the economy, the town had been negotiating with the Tohoku Electric Power Company to set up another nuclear plant in Namie.

We found a perfect ghost town where life ceased to exist, as if a light switch had been turned off. Abandoned homes were now inhabited by cats. In the downtown area there were closed stores, including a barbershop and a bakery. All looked as if the employees were on a break. There were tens of bikes left at the train station; a few buses were parked in their designated spots as if waiting for commuters to disembark from a train.

We drove through more silent streets before arriving at an elementary school, which had been in the tsunami's path. The school building was destroyed, but the children

miraculously survived by running to a hill nearby. Inside the building, there were children's lockers with small boxes for crayons. A memorial stupa—a mound-like, Buddhist shrine—stood on the roadside, with flowers and candles.

From the elementary school, we could just barely see what appeared to be the top of the turbine buildings of the Fukushima Daiichi plant. Red and white construction cranes hovered over them. Namie escaped more damage thanks to the prevailing winds, which dispersed much of the fallout toward the ocean. And what if that second nuclear plant had already been up and running when disaster struck?

Ironically, Namie had been lucky. Things could have been much worse.

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Harness the Sun: America's Quest for a Solar-Powered Future

by Philip Warburg, Boston, Beacon Press, 2015, 250 pages, \$27.95, ISBN 978-0-8070-3376-0.

Not too long ago solar power was still in the experimental stage. Except, perhaps, for heating water and some minor residential installations it was a technology that might be useful in the future but was not yet ready for application. Warburg shows that in recent years solar power has greatly advanced. Besides many residential installations, there are installations in commercial buildings. And electrical utilities are served by large installations on brownfields and public lands. All of this solar power development has been made possible by reduction in price and increase in efficiency of photovoltaic panels as well as by federal and state subsidies.

By the end of 2014 residential solar installations had reached nearly 600,000 homes, about 1 in every 200. Warburg himself has installed solar panels on the roofs of his house and garage. These supply about 75% of his electric power including the daily charging of an electric car. Residential installations can be paid for directly by the householder who then owns the installation. The householder can also lease the installation or finance it through a "power purchase agreement" in which the householder pays nothing up front but must buy all of the power generated by the installation, typically at a rate that is lower than that of electricity from the grid.

Commercial installations include apartment and university buildings, factories, sports arenas, and shopping centers. Many of these installations are placed on canopies over parking areas and walkways as well as on the flat roofs of large buildings. Two universities that have gone heavily into solar power are Arizona State University and Rutgers University. The installations at ASU include a solar canopy on the Farrington Softball Stadium that not only provides power but also shades the spectators. Other sports arenas that have installed solar panels are the New England Patriots Gillette Stadium and the Washington Redskins' FedEx Field. Many large corporations have installed or plan to install solar panels on their buildings. These include Apple, Google, Costco, Kohl's, Macy's, Staples, Toys R Us, Walgreens, and Walmart. Walmart is a leader in solar power with installations on more than 250 of its stores and plans to reach 1000 stores by 2020.

Supplying solar power to electric utilities requires solar installations covering large areas of land. Brownfields, highly contaminated industrial sites and closed landfills, are unsuitable for most purposes but are ideal locations for large solar installations. Solar installations are going up on closed landfills in New Jersey and on an abandoned industrial site in Chicago. Some companies have installed solar panels on brownfields that they still occupy. Aerojet Rocketdyne in California is using solar arrays to provide part of the power needed to clean up polluted groundwater from previous operations.

Overall the EPA has identified brownfield solar projects on landfills in twelve states, hazardous waste sites in ten states, and abandoned factories and mines in several others. These installations have turned liabilities into assets.

Rooftops, parking lots, and brownfields do not have the potential to satisfy the solar power needs of the country. There is, therefore, interest in developing utility-scale solar projects on public lands. Many of these projects are in the southwest where large desert areas and sunny days present excellent conditions for solar power. However, other parts of the country, even New England, have the potential to provide significant solar power. Currently solar arrays have been set up on large areas of public lands in several states including Arizona and California. In addition several Native American tribes are considering investing in solar power on their reservations.

These large utility-scale solar projects have led to concern about environmental impacts and other problems. These projects cover vast areas of land that is largely taken away from other uses. Environmentalists are concerned with the loss of natural habitat with the consequent impact on biodiversity particularly on endangered species. People living in the vicinity of solar installations are concerned with the loss of recreational use of the land and of scenic views. To deal with these problems solar companies are planning to limit their impact on the environment. Solar panels are spaced far enough apart so that they don't shade each other and leave sufficient space for grass to grow and for animals to move under them. Endangered animals have been relocated either permanently or sometimes temporarily during construction. Areas of land much larger than the areas devoted to solar panels have been set aside as natural areas.

The solar power installations described above are based on photovoltaic panels. In addition Warburg discusses some large installations that use mirrors to focus light and heat a suitable substance, typically molten salt. This heat is then used to produce steam to run standard steam turbines. In addition to the problems posed by photovoltaic panels a concern of these installations is that the intense heat produced by the focused sunlight might kill birds that fly through.

Although mostly devoted to applications of solar power the book also discusses the manufacture of photovoltaic panels and plans for the disposal of panels that have outlived their usefulness. It also considers the financial aspects of solar energy and its impact on the economy. Warburg gives an excellent discussion of the present status of solar energy, its problems, and its prospects for the future. This book is a must read for anyone interested in solar energy.

I noticed one small error: On p. 145, Warburg writes "... assuring a consistent flow of photons ..." and a few lines later "...which will channel the flow of photons ..." He means to say electrons rather than photons.

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Andrei Sakharov: The Conscience of Humanity

Edited by Sidney D. Drell and George P. Shultz, (Hoover Institution Press, 2015), 164 pp, \$19.95, ISBN 978-0-8179-1895-8 (paperback)

Andrei Sakharov was awarded the 1975 Nobel Peace Prize. He is one of very few scientists awarded the Peace Prize; others include chemist Linus Pauling, who received the award for his work opposing nuclear weapons testing, and physicist Joseph Rotblat, who shared the award with the Pugwash Conferences on Science and World Affairs, of which he was co-founder (with Bertrand Russell). In the words of Sakharov's award citation, he was awarded the Peace Prize because he "emphasised that Man's inviolable rights provide the only safe foundation for genuine and enduring international cooperation."

The subtitle for the volume edited by physicist and arms control expert Sidney Drell and former U.S. Secretary of State George Shultz is a variation on the Norwegian Prize Committee's description of Sakharov as "a spokesman for the conscience of mankind." The book consists of eleven essays based on presentations at a two-day conference held at the Hoover Institution in December 2014, the month of the 25th anniversary of Sakharov's death. According to the preface, new threats have joined the nuclear threat, and Sakharov's "work and thinking can serve as fixed reference points for an effort to find solutions that must also emerge on a global scale."

This reviewer was a graduate student when he first encountered Sakharov as author of the essay "Reflections on progress, peaceful coexistence, and intellectual freedom" nearly fifty years ago. The debate about anti-ballistic missile systems loomed large at the time, and his essay made the case that such systems would undermine mutual nuclear deterrence. But Sakharov's essay was about much more than that issue. Thinking back, I believe that it changed the way I thought about the world, and that I was one among many on whom Sakharov's essay made a lasting impression.

The editors should be commended for getting these conference proceedings into print. The presenters include a journalist, veterans of the US military and the Foreign Service, theologians, scholars of science and international studies, and others. As is usually the case with collections from a conference, I found several of the essays more interesting and valuable than others. Here I will focus on two essays which were favorites of mine.

Particularly valuable for me was the opening chapter, "The Evolution of Andrei Sakharov's Thinking" by journalist Serge Schmemmann, Moscow bureau chief for the New York Times for many years. Here's an excerpt: "Sakharov's own path from a willing servant of the state to a dissident willing to starve himself to death for a young woman's right to emigrate was hardly rapid or linear.... It took his thinking decades to evolve from the belief in the Soviet state as the prototype for the future world, to a sense that all governments are bad, and finally to the realization that the messianic pretensions of the Soviet state created a unique system of totalitarian repression." At the conclusion of his essay, Schmemmann lets Sakharov speak for himself: "I'm no politician, no prophet, and certainly no angel.... As I never tire of repeating, life is a complicated thing.... Most important, I have tried to be true to myself and my destiny."

Another especially interesting essay is taken from the second day of the conference. The author, David Holloway, is a scholar of international history, especially the history of the nuclear age. His essay is entitled "Moral Reasoning and Practical Purpose." Holloway begins by briefly but vividly tracing Sakharov's evolution from nuclear weapons scientist to human rights campaigner held in internal exile. He then frames three large issues that Sakharov addressed: the relationship between science and politics, the imperfect integrity of scientists, and the distinction between "ethics of responsibility" and "ethics of principle." Near the end of the essay, Holloway recounts Sakharov's reply to a Swedish journalist who prompted him as follows in 1973: "You are doubtful that anything in general can be done to improve the system of the Soviet Union, yet you yourself go ahead acting, writing declarations, protests—why?" Sakharov's answer: "Well, there is a need to create ideals even when you can't see any route by which to achieve them, because if there are no ideals then there can be no hope and then one would be completely in the dark."

This volume could play a valuable role in a seminar or university course on international security, the social responsibility of scientists, or the role of science in international history. Although there is some biographical coverage of Sakharov, I would recommend that those using book precede it with an extended visit to the Sakharov exhibit on the website of AIP's Center for the History of Physics: <https://www.aip.org/history/exhibits/sakharov/>.

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