Physicist Makes Thin Films for Tough Conditions

By Gabriel Popkin

Next time you fly, think about the demanding conditions an airplane’s windows have to handle. Temperatures that can dip far below freezing, and bombardment by dust particles at more than 500 miles per hour. One of the people who help keep airplane windows ice-free and transparent in all conditions is Amethyst Radcliffe, a materials engineer at PPG Aerospace who graduated in 2014 from California State University, Long Beach with a bachelor’s degree in physics.

Radcliffe isn’t someone who knew she was going to be a physicist since age three. In fact, a high school teacher who recognized her talent in the subject had to plead with her to try harder in class. During her undergraduate years, however, Radcliffe realized she was unsatisfied with the job prospects in art (her initial choice of major), and an advisor convinced her to make the switch. “Physics was sort of stalked me until I decided I wasn’t going to fight destiny anymore,” she says.

Radcliffe gravitated toward the borderlands of physics and chemistry — how the arrangements of atoms and electrons in solids give materials the bulk properties that we’re familiar with — electrical conductivity, heat capacity, interactions with light, and so on. She studied enzymes in a biochemistry lab on campus, and did summer research internships at NASA’s Jet Propulsion Laboratory in Pasadena, California and at the Department of Energy’s Los Alamos National Laboratory. She took courses to learn lab techniques such as X-ray diffraction, vacuum sputtering, and atomic force microscopy. As Radcliffe neared graduation, she realized she was not tempted to follow her professors’ career tracks into academia. She wanted to work in a faster-paced environment and to tackle problems that would have more immediate real-world impacts or could lead to new products.

Though she wasn’t aiming specifically for an engineering career, an opportunity opened up for a materials engineer at the paint and coatings manufacturer PPG Aerospace which she took.

It wasn’t so much the title I cared about as much as the job description,” she says.

Radcliffe graduated on a Friday in the spring of 2014 and started at PPG the following Monday. For the past two years, she has developed thin metal films that coat the windows, windshields, and canopies of airplanes. Thin films are ubiquitous in modern technology, used in everything from solar panels and laptops to eyeglasses and pharmaceuticals. Often the properties of the film material — for example, how it absorbs or emits light — must be tailored to meet the specifications for a particular device or application. The films Radcliffe develops are critical for keeping airplane surfaces ice-free — crucial for safe takeoff and flying in cold air — as well as shielding planes from electromagnetic interference and maintaining transparency in demanding conditions.

Much of what Radcliffe does is conducting theoretical studies to predict the properties of a particular material, and experiments to test predictions. But an academic physicist would typically stop there, publishing and presenting results for colleagues in industry to pick up and turn the rest of the way to a commercial product. Radcliffe, by contrast, will continue working with a material until it’s rolling off the assembly line.

She also reads the scientific literature to get ideas for new projects, keeps management informed about project progress through presentations and reports, and interacts with vendors. “Every day is different.”

RADCLIFFE continued on page 6
Members in the Media

“The way transitions happen is like a flock of birds, a school of fish... There’s no one fish saying, ‘Hey, I want everyone to be about five inches away from someone else, and we’re going to have this shape.’”

Neil Johnson, University of Miami, News, June 17, 2016, on the tracking of terrorists on social media.

“Our society has embraced social media. We’re all students of social networks. We could learn a lot from studying social networks.”


“I love chocolate and eat it quite frequently,” he said. “I will eat more chocolate once it has less fat.”

Andrew Ludlow, University of Virginia, The Chicago Tribune, June 15, 2016, on the evidence of a mysterious fifth force of nature.

“It certainly isn’t the first thing I would have written down if I were allowed to augment the standard model at will... Perhaps we are seeing our first glimpse into physics beyond the visible Universe.”


“For the first time, we’ve been able to understand their language and understand what they’re telling us.”

Lawrence Townsend, University of Tennessee, Knoxville, CBS News, May 24, 2016, on the risks associated with future Mars missions.

“This isn’t too early to jump up and down... [and] say the universe is messaging with us.”

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“My goal is neither to be an alarmist, nor to sidetrack future human explorations in deep space. Instead, I hope to point out that prudence suggests that we better understand [solar superflares], their ramifications for future spacelife, and what is needed to protect crews from them.”

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Barry Barish, a professor at Caltech and 2011 APS president, announced on October 22 that he will be stepping down from those duties to devote full time to his new position on the APS senior management team. Since 2013, he has been based part-time at the Laboratory for Laser Energetics (LLE) in Ridge, NY. Until then, Editorial Director Daniel Kulp will continue as interim Editor in Chief. APS expects to begin promptly the search for a new lead editor for Physical Review Letters.

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Confirming Coulomb

“I enjoyed the “This Month in Physics History” article about Coulomb’s experiments in the June 2016 issue. When I was a grad student at Columbia in the 1970s, Samuel Devons tried to reproduce the experiments using only technological replication available to Coulomb. Devons found it very difficult to reproduce the experiments.”

John Farley
Las Vegas, Nevada

Basic Research Benefits

Lawrence Krauss makes many good points in his Back Page article (APS News, May 2016) comparing the LIGO discovery to the appreciation of aesthetic things of culture like art, music, and literature. I would add that, in addition to advancing understanding of our universe and ourselves within it, past evidence proves that even seemingly remote and “trivial” events such as this will always eventually lead to profound practical benefits to humankind; it’s just a matter of time.

There are many examples in science in which such a link can be traced back to a point. While the LIGO event is the province of general relativity, another such case is from special relativity concerning correcting the transformation equations between inertial reference frames from the Galilean group to the Lorentz group. The point seems trivial as it has no real practical, everyday consequence except at speeds close to light, so who cares? However, this “trivial” point ultimately led to our ability to unleash the energy of the atomic nucleus (for good or bad) through Einstein’s mass-energy equivalence, which has had profound practical effects on human-kind from bombs to nuclear energy. Another example would be the revolution of quantum mechanics. The general public might have asked at the time, “Who cares if I put a free particle, which can have any energy, in a box and the box somehow tells the particle what energy it is now allowed and not allowed to have; while interesting, of what practical benefit is it to human-kind?” However, the practical benefits to human kind have once again been profound, with all sorts of implications to semiconductors, lasers, communications, medical imaging technologies, etc. There are many other examples that could be cited also.

It is my belief that the U.S. Congress should be made aware of this and continue to fund this kind of research, and even support basic-research with the idea that it was possible.” In 2013, ESA announced a science theme of “The Gravitational Universe” for the third large-class mission (L3) component of its Cosmic Vision 2015 - 2025 program, which solidified LISA’s position in ESA’s long-term planning.

FRESNEL continued from page 2

len comprised of rings of glass prisms, resembling a giant beehive, with a lamp in the center. Thomas Young in 1824, “All the prisms, resembling a giant beehive, with a lamp in the center. Those prisms serve to bend and concent- rate light from the lamp (or other light source) into a bright beam that travels further and is easier to see, even in foggy conditions.

Fresnel’s design was so effec- tive that such lenses continued to be widely used in lighthouses until the mid-20th century. For a time, Fresnel lenses were used in the headlamps of cars, and they are still used on lighthouses and backup lights, and also in solar cookers. They are also common in lighting for film and theater — not only do they produce a brighter beam, but the light intensity is more uniform.

For all his successes, Fresnel never achieved fame as a scientist in his lifetime. Many of his papers were published posthumously. He did earn the respect of his peers, and his name is inscribed on the Eiffel Tower, along with the names of 71 other French luminaries. Yet Fresnel was never one to seek out the spotlight. As he wrote to Thomas Young in 1824, “All the compliments that I have received from Arago, Laplace, and Biot never gave me so much pleasure as the discovery of a theoretic truth, or the confirmation of a calculation by experiment.” He died of consumption on July 14, 1827, at Ville-d’Avray in France.

Further Reading:

Biased Grades

I was pleased to see Emily Conover’s article “Physics Grading Biased Against Women” in the April 2016 APS News. For many years I, too, used a grading rubric.

WAVES continued from page 1

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SAMES Dunn

In the 2000s, NASA and ESA collaborated on developing a Laser Interferometer Space Antenna (LISA), a triangular interferometer with arms several million kilometers on a side that would have been launched into orbit around the Sun. However, NASA withdrew from the collaboration in 2011 due to budget cuts, and ESA continued to develop the technologies necessary for LISA. “ESA took a gamble,” says Paul McNamara, a astro- physicist at ESA and the deputy project scientist for LISA. “They wanted the science, and they spent a large chunk of money to demon- strate that it was possible.” In 2013, ESA announced a science theme of “The Gravitational Universe” for the third large-class mission (L3) component of its Cosmic Vision 2015 - 2025 program, which solidified LISA’s position in ESA’s long-term planning.

Before NASA withdrew from the collaboration, the two aven- ues had decided to develop a small spacecraft to test the tech- nologies necessary for a successful LISA mission. In December 2015, ESA launched that space- craft, called LISA Pathfinder, to the L1 Lagrange point 1.5 million kilometers from Earth. One of the primary science goals of LISA Pathfinder was to demonstrate that two paperweight-sized cubes of gold and platinum onboard the spacecraft could be shielded from all forces save for gravity. “LISA Pathfinder shows that we can put a test mass in perfect free fall, which is what we’re going to do in a full-scale gravitational-wave detect- or,” says NASA’s Thorpe, the U.S. lead for data analysis on the LISA Pathfinder mission.

An orbiting gravitational-wave observatory such as LISA would be complementary to ground-based facilities like LIGO. “The same sources that LIGO sees in their last orbits before inspiral, LISA could see months to years before they merge,” explains Thorpe. “LISA would see some of these sources first and could basi- cally be an early warning system for LIGO and also, more impor- tantly, for telescopes (that mea- sure electromagnetic radiation). That would be transformational science.”

NASA is once again entertain- ing the idea of officially partner- ing with ESA on LISA. The U.S. agency has assembled an “L3 Study Team” to see how NASA might participate in LISA. Scientists and NASA leadership also have their eye on the 2020 Decadal Survey to survey the priorities of the astronomy and astrophysics community. Most major missions require endorse- ment from the Decadal Survey before they can go forward, and previous Decadal Surveys have endorsed a LISA-like mission.

“This science is so compelling, and we’re making great strides with the technology,” remarks Thorpe. “I’d be surprised if the U.S. community didn’t want to be involved.”

Katherine Kornei is a freelance science writer in Portland, Oregon.

Leonard Finegold
Media, Pennsylvania

Washington Dispatch

POLICY UPDATE
ISSUE: APPROPRIATIONS AND AUTHORIZATION BILLS
Congressional committees continued the process of developing fiscal year 2017 spending bills for the Department of Energy (DOE), Department of Defense, National Aeronautics and Space Administration (NASA), National Institutes of Health, National Institute of Standards and Technology (NIST), and National Science Foundation (NSF). Consistent with the fiscal year 2016 - 2017 budget agreement the White House and Congress struck last fall, most science accounts were held to flat funding in committee "markups." Only one bill — appropriations for Energy and Water Development — received the floor of either chamber, and it fell victim to an amendment on lesbian, gay, bisexual, and trans issues that peeled away Republican support for the measure.

With the legislative calendar shortened by the political conventions and the November election, it is likely that Congress will again resort to a short-term continuing resolution that would allow the federal government to function through the beginning of December. In a lame-duck session following the election, Congress will probably wrap almost all fiscal year 2017 spending legislations into an omnibus appropriations bill.

WASHINGTON OFFICE ACTIVITIES
ADVOCACY
At a 2016 APS April Meeting, the APS Office of Public Affairs (OPA) helped 335 meeting attendees make an impact by sending the APS Contact Congress letter to their Senators and Representatives. At the APS Division of Atomic, Molecular, and Optical Physics (DAMOP) meeting, an additional 317 attendees sent letters. This letter addressed science-funding cuts, as well as the impact of child poverty on U.S. STEM Performance in International Student Assessments (known by the acronym PISA). The letter called for Congress to support sustained robust science funding and to request a National Academy of Science study of the child poverty issue. The DAMOP meeting letter focused on the appropriations bills that affect DOE, NSF, NIST, and NIST.

In late April, OPA’s Government Relations Specialist Greg Mack accompanied Scott Franklin, professor of physics and astronomy at Rochester Institute of Technology, and Director of the Center for Extreme Ultraviolet Math Teaching, Learning, & Evaluation, to meetings in House and Senate offices to discuss priorities for the physics community, including science funding, education, and issues faced by women in science.

In June, APS participated in a meeting at the Department of Education with other members of the Physical Sciences Education Policy Coalition, which has representatives from APS, the American Association of Physics Teachers, American Institute of Physics, American Astronomical Society, and the Optical Society. This was a chance to provide guidance to the Department of Education for the creation of a STEM Master Teacher Corps, called for in the Every Student Succeeds Act the president signed into law on December 2015 as a replacement for the 2002 “No Child Left Behind” Act.

MEDIA UPDATE
Sant Dhar, associate professor of physics at Auburn University, published an op-ed on May 21 in the Opelika-Auburn News, urging the United States to step up its commitment to clean-energy research. Read the piece at go.aps.org/294LIt.

PANEL ON PUBLIC AFFAIRS
At its June meeting, the APS Panel on Public Affairs (POPA) considered whether to archive the seven APS Statements up for review in 2016. Five of the seven statements will remain active. Of the two others, Statement 96.2, Energy: The Forgotten Crisis, will undergo a full review, rewrite, and membership evaluation, while Statement 91.5, Reaffirmation of Statement on Visionary Research Facilities Funding, will be reexamined by the Physics & the Public subcommittee for further action.

POPA also approved a recently completed report on helium economics — Responding to the U.S. Research Community’s Liquid Helium Crisis: An Action Plan to Preserve U.S. Innovation. Follow-on activities related to recommendations in the report are being developed. The Physics & the Public subcommittee presented preliminary data on how to overcome obstacles in recruiting teachers in the physical sciences; a full report is expected later this year. The National Security subcommittee proposed a statement on highly enriched uranium (HEU) reactor conversion and a potential study on the obstacles to elimination of HEU civil reactors.

Following the recommendation of POPA, APS has begun a carbon inventory of the Society’s operations. A template for study proposals can be found online, along with a suggestion box for future POPA studies: go.aps.org/90XVv

APS News

Senate Introduces Science Research Legislation

By Sophia Chen

This June, the Senate introduced a bill regulating science research for several federal agencies. The bill, called the America Innovation and Competitiveness Act (S. 3084), will establish policy governing the Department of Energy (DOE), the National Science Foundation (NSF) and the National Institute of Standards and Technology and includes a 4 percent increase in authorized funding for both agencies between FY2017 and FY2018. (These funding levels do not reflect actual dollars appropriated; they are aspirational guidelines for agencies’ budgets.) Last month, Michael Lubell, the executive director of public affairs, spoke to APS News about the bill before its official release. While Lubell’s comments apply to the June 15 working version of the bill, APS News has verified that his comments are applicable to the bill amended by the Senate Committee on Commerce, Science, and Transportation on June 28.

The Senate’s bill marks a return to bipartisan collaboration in research policy, after a polarized two-year battle over the bill’s House counterpart, the America COMPetes Reauthorization Act (P.L. 112-258). Another Senate leader, Senator Gary Peters (D-MI) and Cory Gardner (R-CO), two freshmen senators on the Senate committee, have worked together to gather input from the bill’s sponsors, and provide feedback on a recent draft of the bill, Lubell says. “[The Senate committee] has been very thoughtful in this process,” he says. “That doesn’t mean that I necessarily agree with everything in the draft, but they’ve come up with a mostly reasonable bill.” Lubell says that APS has expressed its support of certain provisions in the bill. In particular, APS supports merit-based peer review and the need to minimize agencies’ administrative burden. APS also supports a section of the bill that pivots attention to NSF’s mid-scale projects that range from $3 million to $40 million. (Examples of current mid-scale projects include the construction of university radio telescope observatories and data management for dark energy observations.) Lubell says that NSF doesn’t have a good strategy for managing these projects. However, some parts of the draft are “problematic,” says Lubell. The bill would create additional oversight of high energy physics research, beyond that currently provided by the High Energy Physics Advisory Panel in the Department of Energy. Although this committee “works quite well” according to Lubell, the bill creates another high-level interagency committee, whose members include the directors of NSF and the National Institutes of Health. “It is not at all clear what this panel would do because it’s at too high a level,” Lubell says.

Furthermore, the bill makes NSF responsible for a portion of the oversight of mid-scale research projects, instead of leaving it to project managers. “It wouldn’t damage the projects, but it creates more red tape,” Lubell says. “If you’re a project manager, you would have to justify to NSF the need for contingency funds.” Lubell says that this provision is in response to NSF’s reported mismanagement of the $433 million National Ecological Observatory Network (NEON), a project for monitoring long-term ecological changes on a continental scale, which Congress approved for construction in 2011. After discovering that NEON was projected to run over its budget by $80 million, NSF fired its contractor in December last year.

POLICY UPDATE
ISSUE: APPROPRIATIONS AND AUTHORIZATION BILLS

International News

Why India Matters

By Sushanta K. Mitra and Vladimir Shiltsev

India has a rich tradition of physics, with such luminaries like J. C. Bose, S. K. Mitra, C. V. Raman, and S. N. Bose, to name a few. Prominent to this is the Nobel laureate Cand. Phys. DSc. Narendra Modi, India is seeing a renewed investment in science and technology, particularly in big science projects. For instance, the bill for India’s largest granting council for science, the Department of Science and Technology (DST), was increased by 17 percent from last year to $660 million. This is coupled with the launch of some boutique programs like Make-in-India and Start-up India, which could boost further investments in particle physics, making subcomponents for the Large Hadron Collider, among other opportunities. India’s physics community is excited about all these new developments, and the global physics community should pay more attention to India’s research and industry to invest more in basic science in India.

There are several notable examples of large U.S.-India collaboration with its international partners in Australia, Germany and the U.K. LIGO, the Laser Interferometer Gravitational-Wave Observatory (LIGO) collaboration, is one to watch. The LIGO-India project has recently received an in-principle approval from India’s Department of Science and Technology (DST). LIGO-India is a planned advanced gravitational-wave observatory to be located in India as part of the worldwide network.

The proposed LIGO-India project will be a collaboration between a consortium of Indian research institutions (Institute of Plasma Research Gandhinagar, Inter University Centre for Astronomy and Astrophysics, Pune and Raja Ramanna Centre for Advanced Technology, Indore), and the LIGO Lab, and will definitely boost scientific exchange with its international partners in the U.S., Australia, Germany and the U.K. With the joint declaration of President Obama and Prime Minister Modi (see go.aps.org/2921BA6), which Congress approved for construction in 2011. After discovering that NEON was projected to run over its budget by $80 million, NSF fired its contractor in December last year.

Another actively developing project with its international partners in the U.S. has been the Joint Center for Astrophysics and Particle Accelerator Facilities (JCAP), headed by J. C. Bose, S. K. Mitra, C. V. Raman, and S. N. Bose, to name a few. Prominent to this is the Nobel laureate Cand. Phys. DSc. Narendra Modi, India is seeing a renewed investment in science and technology, particularly in big science projects. For instance, the bill for India’s largest granting council for science, the Department of Science and Technology (DST), was increased by 17 percent from last year to $660 million. This is coupled with the launch of some boutique programs like Make-in-India and Start-up India, which could boost further investments in particle physics, making subcomponents for the Large Hadron Collider, among other opportunities. India’s physics community is excited about all these new developments, and the global physics community should pay more attention to India’s research and industry to invest more in basic science in India.

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the study, that the wheel’s indicator landed on. “I don’t see the utility, frankly,” Flake said on the show, when the wheel landed on one of Hu’s studies. “I don’t even respond to a request to comment on this story.”

Hu’s offending research consisted of studies on the mechanics of how animals dry themselves, a study on whether body size affects how fast mammals urinate, a look at the functionality of eyelashes in mammals—all supported by National Science Foundation funding. The congressman, who Collins had said “would probably have had a vaccine in time,” quickly withdrew his disdainful comments about one wasteful story after reading a 2014 Huffington Post interview with National Institutes of Health Director Francis Collins that said Collins had said that they “would probably have had a vaccine in time.”

Since then, journalists and scientists have criticized the Flake report’s inaccuracies, ranging from its lack of context to its omission of essential context. But the report still poses a serious problem to the public image of government spending. The funds from studies like these could be diverted to elbow inflation, Flake suggested.

India continues from page 5

Indian scientists have made significant contributions to the Fermilab program. Several students have received their Ph.D. degrees under the Indian Institutions - Fermilab collaboration, so it is natural that India is already taking a very active role in this development. Cumulation of this collective effort was an overwhelming goal of the Memorandum of Understanding between the U.S. and Indian Universities. In 2007, the Accelerator Laboratories, signed on January 9, 2006 to extend the collaboration on accelerator development in both countries. The collaboration enables scientists in the U.S. and India to jointly develop and industrialize the future high-power superconducting radio frequency accelerators, such as the Proton Improvement Plan-II accelerator for neutrino production at Fermilab and, as part of the India’s 12th national plan, two accelerators in India for material sciences, energy, and medical applications. As mentioned by PricewaterhouseCoopers’ 2015 Global Innovation 1000 report, there has been a 115 percent increase in India’s R&D spending from 2007 to 2015, to $28 billion, which is coupled to a 116 percent increase in imports (primarily from the U.S.). This will provide a significant boost to India’s innovation ecosystem. The increased funding from DST would be targeted towards building research centers and business incubators across academic campuses in India, and will facilitate the creation of campus-led start-up spin-off activities. Also, additional funding will help India to take on emerging risks and provide a platform for Indian scientists to take part in “big science” initiatives. With India still struggling to fund its defense spending (the defense budget in the U.S. is about $535 billion per year) and government engineering wage is less than $35,000 per year), this also brings a significant competitive advantage in developing technologies and hardware for various worldwide “big science” projects. India is fully engaged with the Indian physics community through the Indo-U.S. Science and Technology Forum through a partnership to offer student, postdoc, and faculty exchanges. A call for papers for these programs is issued each fall and more information is available at go.apa.org/ixicNwa. Now is an excellent time for U.S. physicists at all levels, from graduate students to senior professors, to capitalize on this growing momentum and engage in more long-term sustainable collaboration between the two countries.

S. K. Mitra is a founder of the Micro and Nanoscale Transport Laboratory and Associate Vice President for research at York College, City University of New York. V. Shiltsev is Director of the Accelerator Physics Center at Fermilab. Both are members of the APS Committee on International Scientific Affairs.

Related information
Inng Gaytensusicicawg-indigo.org
UGO-India (go.apa.org/200243C)
India Institutes Fermilab Consortium (ftp.bit.gov)

American Institute of Physics. The goal is to provide opportunities to put physics into action, Radcliffe says. In the future she envisions pursuing a Ph.D. and doing a research and development laboratory.

“The most rewarding part of what I do is actually working with the students,” she says. “Being surrounded by physics and chemistry as part of my job makes all those years studying for my degree worthwhile.”

Gabriel Popkin is a freelance writer based in Mount Rainier, Maryland.
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ANNOUNCEMENTS

Reviews of Modern Physics

Physical properties of low-dimensional sp²-based carbon nanostructure
V. Meunier, A. G. Souza Filho, E. B. Barros, and M. S. Dresselhaus

This review focuses on the fundamental physical properties of low-dimensional carbon nanostructures (graphene, graphene nanoribbons, and carbon nanotubes), with an emphasis on understanding and utilizing the unique physical properties that make this class of materials ideal building blocks for future nanoscience and nanotechnology development. In-depth discussions of the structural, electronic, vibrational, and transport properties of these carbon nanostructures from both theoretical and experimental standpoints provide a coherent and foundational overview for researchers interested in broader areas of carbon science and related noncarbon systems.

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
How can Physicists Help the Public Make Better Decisions about Science and Technology?

By Joel R. Primack

For more than 40 years APS has worked to improve governmental decision-making, mainly through the Congressional Science Fellowship program and through occasional professional studies of important science and technology issues. We have also censored the public statements of government scientists on the basis of political correctness. Since 1995 was to abolish the Congressional Office of Science Fellows. From participating in such activities, several thousand scientists have now become what former President Science Advisor Neal Lane [3] called “civic scientists.” Democratic decision-making on technological issues has certainly improved as a result. But despite these efforts, the U.S. has continued to have difficulty addressing the crucial technological challenges of our time, including human-caused global climate change. Ever since about 1800, the doubling time for human production of carbon dioxide and other industrial waste products has been about 30 years. In the next 30 years or so, human activity must somehow stop this exponential trend and develop a sustainable relationship with Earth. Our collective impact on planetary systems is now so great that this growth in resource use must slow very quickly, despite global industrialization as an increasing fraction of the world’s people improve their lives. Unfortunately, most people don’t understand the dangers of exponential growth.

Frank von Hippel and I wrote Advice and Dissent: Scientists in the Political Arena [2] during the Nixon administration.

After President Nixon abolished the Presidential Science Advisory Committee, we thought the world would get worse—but we were wrong. For example, President Reagan committed millions of dollars to the Strategic Defense Initiative without critical review — although the 1987 APS study on directed energy weapons subsequently showed that these “Star Wars” projects were extremely unlikely to succeed.

We were not foresees in the 1970s that the Republican Party would wage a war on science and other independent sources of truth [4]. Among the first things that Newt Gingrich’s Republican Congressional majority did when they came to power in 1995 was to abolish the Congressional Office of Technology Assessment and the NSF Science for Citizens Program, and fire the only astronaut who ever headed the Smithsonian Air and Space Museum. Martin Harwit, President George W. Bush’s administration appointed science advisory committees based on who had voted for him, and censored the public statements of government scientists on issues like climate change. The House Science Committee, chaired by Lamar Smith of Texas, has more recently been given sweeping investigative power by the House leadership and is using it to harass scientists. And Oklahoma Senator James Inhofe, chairman of the Senate Environment Committee, claims that global warming is a “hoax.”

We also did not appreciate that prominent physicists like Francis Seitz, National Academy President 1962-1969, would become what historians Naomi Oreskes and Erik Conway called “merchants of doubt” [5], attacking the scientific basis for regulating everything from cigarette smoking to carbon dioxide, claiming in every case that “This is unsettled so action is premature.” Such efforts unfortunately continue to work: Only about one in ten Americans understands that nearly all climate scientists agree on the human-caused global warming is happening. We also did not foresee that people’s religious and political identities would increasingly determine their views on scientific issues like the existence of climate change and in the modern digital era people increasingly get information from sources, including social media, that often confirm their prejudices.

So... What can we as individual scientists do to improve the situation?

First, individual scientists need to get better at explaining our research and also the scientific basis of public policy choices to the public. This is difficult for several reasons. One is because most non-scientists don’t know enough about science, and also because scientific discourse is full of facts, theories, logical arguments, and jargon. We have to become better at presenting science in ways that people can grasp and act on.

Actor Alan Alda for 14 years hosted the Scientific American Frontiers TV show, constantly challenging scientists to explain things in a compelling way. In 2009 he founded the Alan Alda Center for Communicating Science at Stony Brook University. Alda and his team have been giving workshops for scientists about how to reach audiences by telling memorable stories. Most non-scientists quickly grasp ideas expressed as social situations and stories. The Alda team also leads improvisation exercises to help scientists learn to sense how the audience is responding and not overestimate how successfully they are communicating.

Several scientists have also been giving helpful workshops and writing books on communicating science effectively. Randy Olson, a former professor of marine biology turned film-maker, in his 2015 book [6] recommends a dialectical scheme for turning science into stories: background, problem, solution, which he summarizes as “And... But Therefore...”

The present era seems to be ripe for student involvement in hopeful causes. Scientists at colleges and universities can encourage and help our students to organize “Science Workshops on Political and Social Issues” to study important issues and help improve the world. When we were Stanford graduate students, physicist Robert Jaffe and I helped to organize a program of such courses that lasted 20 years and did much good — including helping to launch the Congressional Science Fellowship program.

When scientists become advocates, they may be perceived by their colleagues and the public as biased. But scientists have a right to express their convictions and work for social goals. These activities need not undercut rigorous commitment to objectivity in research.

What can professional scientific societies do?

Excellent science reporting can help, but scientists themselves — particularly diverse and articulate ones — are needed to explain the scientific background for important issues. We need human examples, demonstrating by their presence how a scientist thinks and acts. APS and other professional societies should encourage this by establishing new annual awards to recognize exemplary efforts of this sort by scientists at all stages of their careers.

I also suggest that leading professional societies collaborate to create online authoritative reviews of important issues that is distributed to the public. A recent example of this is the report by the AAAS Climate Science Panel, WHAT WE KNOW: The Reality, Risks, and Response to Climate Change, on the web with an introductory video narrated by the president of the American Meteorological Society [7]. Creating videos and using social media to spread the messages is essential to reach a large audience in the modern world.

When serious disagreements remain about how to interpret the underlying science a policy decision, it is not advisable to paper over the differences. Nancy Ellen Abrams and Steve Berry suggested a better approach that they call Scientific Mediation [8]: Have experts who disagree write a joint report with the help of a mediator, in which they specify the topics on which they agree and disagree, and explain why they disagree on each of these points to each others’ satisfaction, clarifying what additional assumptions they are making. These additional assumptions are often not scientific. Framing and nuclear power might be good topics for this technique.

Don’t be discouraged by the tremendous challenges we face. Richard Feynman advised that in choosing projects, we should maximize the product of the (importance) x (probability of success). And don’t underestimate the probability of success!

Sometimes one’s public activities have unexpected benefits. When I was in Washington in 1976 to work with Senator Kennedys’ hearings and testify on the Science for Citizens bill, the Congressional Science Fellow in Kennedy’s office got me invited to a meeting of President Ford’s Science Advisory Committee that was discussing the proposed “Science Court”. That’s how I met the love of my life, my wife Nancy Ellen Abrams. Nancy was then working at the Ford Foundation, and she had been invited to the Science Advisory Committee meeting in hopes that Ford would fund a trial of the Science Court. Nancy liked my critique of the Science Court at the meeting, one thing led to another and... and we were married the following year. We have subsequently coauthored many articles and two books [9].

Side-benefits are not guaranteed, but scientists and science organizations can improve the way our society deals with issues of science and technology.

[Joel R. Primack is the Distinguished Professor of Physics Emeritus, University of California, Santa Cruz. This article is based on his Leo Szilard Lectureship Award talk at the 2016 April APS Meeting: the complete text and slides are at go.aps.org/290h4v9.]

References:
6. Randy Olson, Houston, We Have a Narrative: Why Science Reporting Can Help, or More Than (2011).
7. The website is whatweknow.aaas.org and the video is at whatweknow.aaas.org/consensus-sense