Theo...y physics. I am deeply honored to have managed TRIUMF through years of transition and growth, and have had great success in positioning the laboratory for a bright and vibrant future."

"I am delighted and excited that Jonathan Bagger has accepted our invitation to be the next CEO of the APS," added APS Past President David Gross, who chaired the CEO Search Committee. "Jon's extensive experience in scientific management and his deep commitment to the APS and to its mission will serve the society well in these tumultuous times."

The members of the CEO Search Committee were: 2019 APS President David Gross (chair), 2020 Speaker of the Council Andrea Liu, 2011 APS President Barry Barish, 2015-2016 APS Committee on Minorities Chair Nadya Mason, 2016-2018 APS Board Member Nick Bigelow, 2020 APS President Philip Bucksbaum, and 2018 Speaker of the Council Tim Gavaler. Bagger has been Director of TRIUMF since 2014. The Canadian

Jonathan Bagger

DIVERSITY

Physics Departments Ditch the GRE in Bid for Equity

BY DANIEL GARISTO

Physicists and astronomy departments at US and Canadian universities are dropping the general Graduate Record Examination (GRE) and physics GRE (PGRE) requirement in droves. Since March, over two dozen departments have abandoned the tests, according to James Guillochon, an astrophysicist formerly at the Harvard-Smithsonian Center for Astrophysics (CFA) who maintains a public list of GRE requirements. A 2019 survey by Science Magazine found that physics programs were among the slowest to drop the GRE. Now, more than half of the programs on Guillochon’s list have permanently done away with the GRE requirement, and a full two-thirds no longer require it for the 2020–2021 admissions cycle. Physics departments have issued statements that "acknowledge the significant disruption" from the COVID-19 pandemic and the difficulties associated with taking the GRE at this time.

"I think that this pandemic has exposed for people in a new way the levels of inequality throughout our society," says Alexander Rudolph, an astronomer at California State Polytechnic University who directs the Cal-Bridge program. "It seems to have incited a real examination of the way culture and systems and societal inequities play themselves out...in particular in graduate admissions."

Although the recent move away from the GREs is primarily driven by the COVID-19 pandemic, it coincides with Black Lives Matter protests and threats to legal immigration from the Trump administration. Physics remains one of the least diverse STEM fields—with only 20 percent of PhDs awarded to women and 5 percent awarded to underrepresented minorities in 2019—and there has been growing pushback against the GREs for years.

"We'll see what happens once COVID is over, whether or not [departments] decide to continue to do admissions more inclusively," says LaNell Williams, a PhD candidate at Harvard. Advocates for dropping these tests claim that the GRE has no bearing on graduate school success and when universities require it, they end up with a less diverse applicant pool. Evidence for both claims has been bolstered by studies in recent years.

"One of the most commonly reported things is, ‘Hey, I took the GRE and I bombed it,’" says Ted Hodapp, APS Director of Project Development and a former director of the APS Bridge program, which aims to increase the number of PhDs awarded to underrepresented minorities in physics. In 2019, Hodapp was coauthor on a study which found the physics GRE did not predict PhD completion. "[We found] that the GRE tends...
Physics History

When Isaac Newton formulated his laws of motion and universal law of gravitation in the 17th century, his contemporaries had foreseen that his work would one day lead to the discovery of a new planet in the solar system: Neptune. Credit for predicting its position in the night sky is historically given to the French astronomer and mathematician Urbain Le Verrier, but Le Verrier had a British rival, John Couch Adams, who independently arrived at the same conclusion.

There is evidence of prior sightings of Neptune after the invention of the telescope: Galileo Galilei in 1612/1613, Jerome Lalande in 1769, and John Herschel in 1830, most notably, although none realized the object they had observed was a planet. Galileo thought it was fixed star, probably because Neptune was going into retrograde (apparently moving in a direction opposite to that of other planets) when he observed it and thus appeared to be stationary. Herschel also mistook Neptune for a star.

However, in 1849, physicist David Jameson, arguing that the second body may have suspected it was a planet. Jameson found a note in one of the astronomer’s notebooks noting the movement of a “background star” on Jameson, who was also marking a dot with a different ink, which Jameson interpreted as having been from an earlier sketch on January 5 — evidence that Galileo was tracking its possible movement. But there is no record of Galileo ever following up on this.

The hunt for a possible new planet was triggered in 1825, when Alexis Bouvard published astronomical tables for the orbit of Uranus. The tables predicted the planet’s position based on Newton’s laws of motion of gravitation, and astronomers began comparing their observations to those tables. That’s how they discovered some significant discrepancies between the predictions and their observations, especially after Uranus had completed one full orbit (in 1842). Following the 1871 discovery by William Herschel. These discrepancies could have been due to the influence of the Sun’s gravity, or the result of observational error. Or they could have been due to the orbit of Uranus being perturbed by another, as-yet-undiscovered planet.

Le Verrier was among those who favored this new planet option. Born in 1811, Le Verrier attended the École Polytechnique, initially studying chemistry before switching to astronomy, with a particular interest in celestial mechanics. He took a job with the Paris Observatory, where he would spend much of his career, serving as director from 1854–1870, and from 1873 until his death in 1877. Following early work on the stability of the solar system and on periodic comets, he turned his attention to the irregularities in Uranus’ orbit, at the urging of the physicist Arago.

On August 31, 1846, Le Verrier presented his calculated position for a new planet to the French Academy, and also sent a letter to Johann Galle at the Berlin Observatory containing his conclusion. Galle wasted no time turning his telescope to the predicted position. The very first night, on September 23, 1846, Galle and his colleague, Heinrich d’Arrest, found Neptune within 1 degree of Le Verrier’s predicted location. It took them less than an hour to do so. Just 17 days later, William Lassell discovered Neptune’s moon, Triton. But controversy broke out soon after. While Le Verrier was making his calculations, a young British mathematician and astronomer named John Couch Adams was doing the same in England. Born in 1819 to a poor tenant farmer in Cornwall, Adams was privately educated, until a chance invention made it possible for him to attend the University of Cambridge to study astronomy. While still an undergraduate, he learned of the discrepancies in Uranus’ orbit, and the possibility of a new planet. Adams thought he should be able to use observational data on Uranus to determine the mass, position, and orbit of that same planet using Newtonian physics.

He continued this work after completing his
rom climate change to the proliferation of nuclear warheads, physics principles are deeply tied to many of society’s most pressing issues. The Forum on Physics and Society (FPS) serves as a home for physicists who are passionate about better understanding, analyzing, and addressing such issues, as well as those actively engaged in efforts to inform the public and advance policymakers on these subjects.

Many physicists affiliated with FPS have gone on to hold influential roles at the highest levels of government. Three FPS members have served as members of the US Congress—Vern Ehlers (R-MI, 1991-2011), Rush Holt (D-NJ, 1999-2015), and Bill Foster (D-IL, 2008-2012)—and another member has worked as science advisors at the State Department, Department of Energy, and even the White House.

FPS was founded in the late 1960s and was formally incorporated as APS in 1972. Amid the political turmoil of the 1960s and 1970s—characterized by the energy crisis, the rise of nuclear weapons proliferation, and an international environmental movement, and a national reckoning over civil rights—many physicists felt a professional responsibility to engage with these societal issues and lend their expertise to the national discussion. Today, with over five thousand members, FPS remains highly engaged with these original interests in energy, climate, nuclear, and national security-related issues, and has also expanded its scope to include newer issues such as artificial intelligence, autonomous weapons, sustainable development, and cybersecurity.

“Scientists and physicists now recognize how important science is not only to their field, but to humanity, the world, and the future. Likewise, policy makers and diplomats have recognized that having stronger connections to science matters for them too,” explained FPS chair Bill Colglazier (American Association for the Advancement of Science, AAAS), former Science and Technology Advisor to the Secretary of State and co-chair of the UN’s Ten-Member Group on Science, technology, and innovation.

While most years the specific workshops and speakers are selected by the FPS Staff, FPS will serve as a pilot program for a newly formed student advisory council to help guide what content is included in the conference.

“Usually each site has input from students as they plan, but for the virtual CUWiP, we came up with a student advisory council to help plan the conference,” says Kai Wright, Senior Coordinator at APS. “This is something we want to continue moving forward with CUWiP, to have student voices in the national organizing committee.”

The formation of a student advisory council will help ensure CUWiP’s activities are useful for student attendees and will add additional perspectives to the planning process.

“The student advisory council was selected in part based on groups we are looking to reach with the CUWiP conference,” says Goertzen. “We also want this council to amplify diverse voices—we want everyone to feel welcome coming to a CUWiP conference.”

Another change to CUWiP being piloted by the 2021 conference is a new date: Usually CUWiP has been held over Martin Luther King Jr. weekend, but organizers are experimenting with shifting the conference date to see if it better accommodates students.

“We’re experimenting with this change to make CUWiP more accessible,” says Goertzen. “We want students to be able to attend CUWiP but also be able to take part in MLK weekend and Day of Service activities.”

Since its inception in 2006 at the University of Southern California, CUWiP has become a hallmark event for undergraduate women in physics, reaching almost every woman in the US who is pursuing a physics degree, according to a recent CUWiP impact report. Funding to support CUWiP and provide an impactful experience for women seeking physics degrees comes from the National Science Foundation, the Department of Energy, the Heising Simons Foundation, and the Alfred P. Sloan Foundation.

Applications for the 2021 CUWiP conference open September 8th and will close on October 30. The application is available on the CUWiP website.

CAREERS
A Successful Summer Webinar Series

BY LEAH POFFENBERGER

A s part of the APS response to the COVID-19 pandemic, APS Career Services, together with Farah Dawood, APS Chapters Program Manager, has been hard at work all summer hosting webinars and online workshops aimed at early career physicists. The Summer Webinar Series, which ran from May to August, included more than 20 online sessions covering topics from career development to mental health and self-care.

While APS has been offering free webinars for a number of years, the Summer Webinar Series ramped up the content available online to support APS members, especially those in early career jobs and early career physicists.

“Before COVID and the Summer Webinars, even getting to fifty to sixty people registering for webinars, but the first Summer Webinar—Building Your Professional Network during COVID—had 400 registrants,” says Crystal Bailey, Head of Career Programs at APS. “People are much more willing to attend webinars now that they’re stuck at home.”

The Summer Webinar Series featured a wide range of resources, specifically in response to anxiety about job opportunities drying up during COVID, and a recognition of the number of early career APS members who are likely facing increased stress.

“During COVID, we wanted to put together a series of webinars in response to COVID, and we know a significant portion of our member community is undergraduates, graduates, early career physicists, basically early career folks who are probably at home worried about all kinds of things,” says Bailey. “We realized that we had an opportunity to provide information that would be useful to them, so Careers teamed up with Dawood to create the Summer Webinar Series.”

To build the series, Dawood started off by sending a survey to early career members of APS to find out what kinds of webinars and workshops would be most useful. As a result, the Summer Webinar Series offered more than 20 different sessions, including both webinars and virtual workshops, on topics ranging from managing workflow and stress to exploring “off the beaten path” physics careers. The virtual workshops provided a complementary component to the large webinars by giving attendees a space to interact with each other and facilitators.

After each webinar session, attendees were able to share feedback, ensuring the series continued to provide relevant and useful information. According to Bailey, most of this feedback has been positive. “Since I am a graduate student close to finishing my PhD program, I learned a lot of things from this webinar. It really helps to prepare me further,” said one participant in the Building Your Professional Path During COVID Webinar.

In addition to the Summer Webinar Series, APS Career Services has put together several workshops and webinars for use by Research Experiences for Undergraduates (REU) sites that have had to operate...
Russia’s nuclear weapons arsenal. The US State Department’s April 2020 report on arms control compliance concludes that Russia remains in compliance with this Treaty. The third Board Statement concerns recent reports that some in Congress and the Trump Administration have expressed interest in resuming nuclear testing. In response, the Board Statement reaffirms the 2018 APS statement that “fully informed technical studies have concluded continued testing is not required to retain confidence in the safety and reliability of the remaining nuclear weapons in the United States’ stockpile. Resumption of nuclear testing may have serious negative international consequences, particularly on the nonproliferation regime.” APS Board Statements are one of the three ways that APS officially comments on public policy matters (in addition to APS Public Policy Statements and Unit Statements).

In general, any APS member, group of members, or APS Membership Unit may submit a proposal for a statement to the APS Panel on Public Affairs (POPA).

The APS Board of Directors or its Executive Committee (IEC) may decide that an especially timely issue requires an expedited statement, in which case they will draft a Board Statement, assisted by the POPA Steering Committee. As part of the review process, POPA obtains comments from the APS Public Policy Committee, the APS Council Steering Committee, and the APS Office of Government Affairs.

Following any revisions, the Board approves the statement and it is distributed to the membership. A Board Statement is archived after one year, but may become an APS Public Policy Statement if it goes through a more extensive review. (For details on procedures for APS Statements see aps.org/about/government/documents/joint.cfm.)

Government Affairs

APS Pushes Back on White House Executive Actions that Threaten International Students

BY TAWANDA W. JOHNSON

D uring the past several months, APS leaders, staff, and members have diligently worked to push back against White House executive actions that harm international students who are essential to the sciences community and vital to the US scientific enterprise. Immigration and Customs Enforcement (ICE) announced the most recent rule change on July 6, which would have forced international students currently in the US to return to their home countries or cease their educational institution offering in-person instruction if their current institution was offering only online courses this fall. In response, on July 8, APS leadership sent a letter to members, alerting them to steps the organization was taking to fight the ICE directive, including a phone-in campaign organized by the APS Office of Government Affairs (APS OGA).

After Harvard and MIT filed suit against the rule, APS wrote an amicus brief to support their case. Sixteen scientific organizations, including the American Association for the Advancement of Science and the Optical Society, joined the APS brief in support. Apparently caving to this widespread opposition, ICE rescinded the directive, reverting to its March 9 guidance. That guidance enables current international students to take a course load that includes online classes due to the pandemic, but prevents new students from entering the US for online-only classes. “The government capitulated entirely,” said APS President Phil Bucksbaum. “These actions show the importance of an organization reacting quickly, and they also show that the science community can truly make a difference.”

Regarding other recent actions, including the August 3 proclamation on June 22, impacting the H-1B visa program and some categories for J-1 visas. According to the American Immigration Council, “the H-1B is a temporary (non-immigrant) visa category that allows employers to petition for highly educated foreign professionals to work in specialty occupations that require at least a bachelor’s degree or the equivalent.” Also according to the Council, “14,000 holders enter the United States on a work-based program, including as a research assistant. Because APS had heard reports weeks earlier of a possible threat to the Optional Practical Training (OPT) program from the proclamation, APS OGA, with support from the Society’s Office of International Affairs and Office of Industrial Engagement, developed a plan to get the word out to House Republicans about the importance of OPT. The OPT program enables highly skilled international students who completed their studies in the US to gain work experience for a period of time and is used as a recruiting tool by...

Host a Conference for Undergraduate Women in Physics in 2022

APS is now accepting applications for host site institutions for the 2022 conferences. Application deadline November 1, 2020.

Learn more go.aps.org/cwuw-host

2022 CUWWiP

#apscuwuw

FYI: SCIENCE POLICY NEWS FROM AIP

Pandemic Taking Heavy Toll on Scientific Workforce

BY MITCH AMBROSE

A grim picture is emerging of the pandemic’s disruptions to the US scientific enterprise, with the costs of lost research, project delays, and other expenses already running into the tens of billions of dollars. The American Association of Universities, which represents 63 leading US research institutions, has estimated the combined costs of the pandemic to its members for the year will range between $30 billion and $52 billion. The Association of Public and Land- grant Universities has projected its 466 members will face around $45 billion in lost research funding, with other research groups, they have proposed (go.aps.org/08t96r) that Congress distribute at least $50 billion across scientific agencies to support research recovery activi- ties at the US optical opposition, ICE rescinded the directive, reverting to its March 9 guidance. That guidance enables current international students to take a course load that includes online classes.

The task force anticipates that

an ongoing accelerator upgrade due to pandemic-related delays. In a high–impact scenario, the department estimates the project will require an additional $30 million and 15 months to complete. A number of other construction projects underway across science agencies face similar challenges. To cope out the broader con- sequences of the pandemic, the American Institute of Physics convened a nine-member task force this spring. Its report (go.aps.org/0pi52p) stressed that curtailed international exchange, reduced job opportunities for early career researchers, and knock–on effects of university budget contractions could severely diminish the physical sciences workforce.

The task force anticipates that

widespread work slowdowns, anx- ieties about potential layoffs and diminished career prospects, and mental health concerns. While a handful of people reported being more productive, the average estimated efficiency of work from home arrangements was 78%, and some respondents with childcare responsibilities reported efficiencies as low as 5%. One wrote, “Every scientist I know with small children is facing a complete breakdown of their ability to accomplish anything, all of us is very low-quality, and despite being exhausted beyond anything I have ever accomplished, I am slipping ever–further behind my peers.” Respondents also raised concerns about how new visa restrictions could impair recruitment and how continuing new restrictions could prevent US researchers from flying to Europe to visit CERN, which hosts the Large Hadron Collider.

Disruptions to work at the LHC itself are also coming into focus. The Department of Energy reports (go.aps.org/3axPXfk) it will have to reset its baseline cost and schedule commitments to...

Go to the Preface

Submit your research and APS will pay your article publication charges through a more extensive review.

First content from PRX Quantum is now live, featuring quantum information science and technology research with an emphasis on testing and profound impact.

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Joan Feynman 1927–2020

OBITUARY

Joan Feynman was awarded a bachelor’s degree from Oberlin College, and she attended Syracuse University, studying condensed matter theory and earning a PhD in 1958. By 1960, Feynman was married with two children and, having not secured the kind of research position she was looking for, she decided to take a break from physics to take on the role of homemaker.

The break was short-lived, as Feynman grew depressed from the drudgery of keeping a home and caring for two small children. In 1962, at the advice of a therapist, she went in search of employment, securing three job offers at Columbia University’s Lamont-Doherty Earth Observatory. At Lamont, where she worked part-time, Feynman began her research into Earth’s magnetosphere, identifying its shape. In 1975, Feynman accepted a job at the NASA Ames Research Center, where she developed a way to detect solar coronal mass ejections from the sun by searching for the presence of helium in solar wind. She would go on to hold positions at the High Altitude Observatory at the National Center for Atmospheric Research in Boulder, Colorado; the National Oceanic and Atmospheric Administration in Washington, D.C.; and the University of California, where she would conduct research until her retirement.

As part of her research at JPL, Feynman identified the mechanism that leads to the formation of auroras and developed a statistical model to determine the number of high-energy particles expelled from corona mass injections that would hit a spacecraft during its lifetime. After her retirement from a senior scientist position in 2003, Feynman continued to conduct research on the impact of solar activity on the early climate of the Earth and the role of climate stabilization in the development of agriculture.

“Joan Feynman leaves a legacy of exemplary scientific research, having made important contributions to our understanding of the solar wind, the Earth’s magnetosphere, and the origin of auroras,” said APS CEO Kate Kirby. “Despite being discouraged to pursue science by women in her family, she persevered, and her accomplishments serve as an inspiration to women who wish to pursue a career in science.”

OBSERVED CONFLICT OF INTEREST

The APS Editorial Office has also been offering webinars on topics like writing a great scientific paper, further increasing the reach of information APS members can access from the safety of home. As a few examples, African Physics Newsletter and the APS Forum on International Physics (FIP) Newsletter, and publishing statistics from the Physical Review Journals for every country involved. Likewise, physicists can view APS membership statistics for the winners of APS Prizes and Awards in their region.

But to better serve international physicists, APS also must communicate opportunities and services for all physicists outside the United States. Toward this end, the Society created a tool, APS International Engagement Around the World (IAEW), which connects international members with other physicists in their country or region.

Through the IAEW tool, any physicist in any country can see how they can participate in APS and how the Society engages with their community. The opportunities and information highlighted on each page of this web tool will continue to grow and evolve across all areas of APS—from membership to programs to publications and advocacy on behalf of international physicists.

The heart of the IAEW web tool is the way it provides a chance for all physicists to participate in APS activities, connect to international offerings, and tap into the conversations and publications related to their local community. This effort resulted in a report, recommendations, and implementation plan to guide the Society as it aims to better serve the communities.

To address this concern, APS launched the Task Force on Expanding International Engagement in March 2017. The Task Force, which was created with assessing APS member interests and identifying goals and recommendations for increasing the scope of engagement with APS members and international physicists. This effort resulted in a report, recommendations, and implementation plan to guide the Society as it aims to better serve its communities.

As the summer comes to a close, APS Webinars will continue in the fall, with new content covering a variety of careers topics. “People have been really happy with what we’re doing, and we’re happy to build on that momentum—this is obviously something that we’re offering that is valuable to the community,” said Bailey. “The plan moving forward is to maintain the content of offering regular webinar presentations on specific professional development themes, for example careers in industry.”

APS Careers is also working to launch a professional development e-mail series called “Shape-Up” to help participants keep track of their professional development goals through small, actionable tasks. With this in mind, APS welcomes feedback from you regarding what programs, opportunities, and resources would be most useful to physicists in your region. Please contact the APS Office of International Engagement at internationalservices@aps.org to give your input on how APS can better serve your region and what you would like to see from our new tool, APS International Engagement Around the World.
widely acknowledged that culture
the first kickoff meeting, it was
aware of the social science lit -
about concepts for improving
know one another and learning
first chance to begin getting to
both of which had identical content
what is called ‘shared leadership.’”
people at the top have the power
you need that,” says Plisch. “The
also folks who are more junior or
of Physics and Astrophysics at
APS-IDEA steering committee
in science and technology areas.
there is a need for connection to
- consisting of their relevance

to crisis response.
the financial toll will be “par -
certainly disastrous” for Historically
Black Colleges and Universities
(HBCUs), anticipating the pandemic will “slow the outstanding contri-
butions that HBCUs have made toward
to creating a more diverse physical
science community.”

The task force nevertheless
does identify some opportuni-
ties for change. Among them, observing that the expanded use of
virtual teaching and conference tools could help engage previously
unreached communities, the task
force states: “A parallel increase in
the number interested in the physical sciences is occurring, so there is
high-quality instruction
and the case is made strongly
that physical sciences advances are
critical to addressing crises of
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military nature.”
The author is Acting Director of FYI.
Published by the American Institute of Physics since 1989, FYI
is a service of the National Science Policy news that is read by congressional staff, federal agency heads, and
leading figures in the scientific community. Sign up for free e-mail alerts at apifyi.org/dfyi.

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leading figures in the scientific community. Sign up for free e-mail alerts at apifyi.org/dfyi.
Gives physicists with an interest in Science Fellows program, which FPS is also very involved with the arms, energy, and climate change. Society—in particular, nuclear society. Since 1982, FPS has organized deep connections with issues of science and technology; and (4) a duty for scientists to marshal science and technology; and (2) A duty for scientists, policymakers, and the public; (2) A duty for scientists, policymakers, and the public; (3) A duty for scientists, policymakers, and the public; (3) A duty for scientists, policymakers, and the public.

FPS offers its members several opportunities to engage more deeply with issues of science and society. For example, the award-winning APS Physics magazine, which is a free online magazine featuring news and commentary about cutting-edge research published in the Physical Review journals.

In the age of the novel coronavirus, a newfound focus within physics is how physicists can contribute to the COVID-19 response. APS members have been involved in the development of low-cost, rapidly built mechanical ventilators to meet the current ventilator shortage, elucidating the fluid dynamics of respiratory droplet transport, and the international effort to repurpose physics infrastructure such as x-ray facilities, cryo-microscopy, lasers, and NMR for urgently-needed research related to COVID-19. More broadly, FPS members have been involved in dissecting how the United States, despite having one of the most sophisticated scientific and advising policymakers and the public about the threat of new technological challenges in future generations of crises. (2) A duty for scientists to inform the public about the risks and consequences of emerging technologies. (3) A duty for scientists to inform policymakers and the public about the threat of new technological challenges in future generations of crises. (4) A duty for scientists to inform policymakers and the public about the threat of new technological challenges in future generations of crises.

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A functional quantum internet, a network in which information stored in qubits is shared over long distances through entanglement, would change the fields of secure communication, data storage, precision sensing, and computing [1, 2]. Innovations in these fields would alter society—for example, we trust that enhanced privacy would strengthen democratic institutions—but building such a network will be a complex task.

A whole zoo of components will need to be developed and integrated, from quantum transducers and quantum memories to classical light sources and classical communication channels [3]. And because of the scale of the potential impact, understanding challenges and consequences not quite yet thought through [4], the scientific community will need to consult social scientists, legal experts, and historians to ensure that the benefits of this new technology are widely and equitably shared across society.

To achieve these ambitious ends, we believe the quantum science community may have to structure itself differently—to embrace a larger-scale venture with expertise spanning science, technology, and society. It conjures up the seemingly commonplace in astrophysics and cosmology, and modern efforts that required extraordinary financial resources and scope scientific enterprise. It conjures up the seemingly industrious experience of other research communities, such as high energy physics, astronomy, and aerospace. We think that it is time for serious reflection and collaboration.

This collaborative depth is unlikely even in the large, international collaborations that are required. Any large-scale demonstration—will require hundreds of researchers from many groups to coordinate their efforts. The incentive to produce components that are useful for integration into a larger system, which requires central organization and long-term planning, are comparatively small.

To give an example from the field of quantum memories, individual groups have often focused on maximizing one specific metric, such as memory efficiency, storage time, or bandwidth without regard to systems-level demands. To build a trans-continental quantum network—or any large-scale demonstration—will require hundreds of researchers from many groups to coordinate their efforts. This collaborative depth is unlikely even in the large, multinational projects such as those in Europe. Joint funding, even on a large scale, is not the same as real collaboration.

In light of these deficiencies in the current funding models, there is a need to rethink reflection and discussion about how to organize large-scale efforts in quantum networks. While one size is unlikely to fit all, the experience of other research communities, such as high energy physics and astronomy, who went through this type of organizational change decades ago, can provide useful examples that encourage this process.

What can we learn from Big Science?

"Big Science," a term popularized by Oak Ridge National Laboratory’s then-Director Alvin M. Weinberg, has been used to describe the 20th century’s large-scale and large-scope scientific enterprise. It conjures up the seemingly unending supply of instruments and budgets within large collaborations—collaborations aimed at fundamental science goals that are too expensive for one group to pursue on their own. The history of nuclear and high energy physics is filled with postwar efforts that required extraordinary financial resources and large-scale efforts. Today, national and global projects are also commonplace in astrophysics and cosmology, and modern successes for this model include LIGO’s observation of gravitational waves and the LHC’s discovery of the Higgs boson.

Several fields, including materials science and condensed matter physics, have embraced large laboratories (e.g. photon sources are built at SLAC and the Advanced Photon Source at ANL) while maintaining a diverse collection of small experiments. In this model, one big facility generates and provides beams to several projects. Indeed, these big facilities have become critical resources in experimental efforts spanning biology, chemistry, and engineering, to name a few. Industrial researchers also use big facilities to develop new technologies and better materials, batteries, etc; in this way, the big science of the 20th century is becoming the big “networked science” of the 21st century, wherein small efforts and industry are integrated into a larger facility.

The quantum internet is not benchtop science

While not all problems in quantum science and technology require large collaborations at this stage, building a functional quantum internet is a different type of challenge compared to, for example, building quantum computers. Coordination between many actors is much more important for networks. The incentives are not the same. Quantum computing has clear industrial motivations. In contrast, many of the motivations for quantum networks are societal benefits that may be harder to monetize in the near term, such as enhanced privacy and security. A comparative study of the development of classical information technology strengthens this point. The internet and the World Wide Web originally grew out of public rather than commercial initiatives (ARPANET and CERN, respectively).

Historically, big science approaches have been adopted when exciting common goals are coupled to comparatively insurmountable technical challenges. Even under these conditions, transitions to big science—in high energy physics, astronomy, and elsewhere—have not been trivial. Robert Wilson, the founding director of Fermilab, strongly expressed his unhappiness about the level of bureaucracy that was involved in running big projects [5]. And, as Norm Augustine postulated, “If a sufficient number of management layers are superimposed on each other, it can be assured that disaster is not left to chance.” Yet the high energy physics research community grew supportive (on the whole) of this direction because it recognized that there was simply no other way to achieve its scientific goals.

The quantum internet will be international

The quantum internet is by definition global, so different nations will have to agree on technologies and standards. The network will necessarily involve many different technologies and platforms, so the respective communities must work together starting from the definition of the scientific scope, the goals, the roadmap, the deliverables, the funding profile and all the feasibility demonstrations (such as for example in [6]) needed to address the challenges and build up a functional quantum internet.

In the United States NIST-sponsored and industry-supported Quantum Economy Development Consortium (QED-C) is charged with enabling the development of a supply chain for quantum devices and systems. QED-C also works to ensure a well-matched boundary condition between industry, national labs, and academia. These functions will be crucial during the current research and development era—and also during the future quantum-tech era.

The degree of private-public partnership needs special attention, building of trust, and addressing issues of conflicts of interest and regulations. This rests on the recognition that science and, with appropriate resource commitment, the quantum internet can become a major success story in science, technology, and society.

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The Quantum Internet Will Require Bigger Quantum Science

BY CHRISTOPH SIMON AND MARIA SPIROPULU

The quantum internet is another example where a big science approach will be needed. The challenge for quantum science communities in different countries is to find ways of organizing that are compatible with their systems. In the United States, national labs already have experience in coordinating big science projects involving many institutional partners. It may be possible to leverage this experience for quantum science and, in particular, for the quantum internet. We do note that in the United States, the National Quantum Initiative promotes national collaborations that can form a firm basis for international and global projects and a quantum internet blueprint has been recently published by the Department of Energy [2].

With quantum scientists finding effective ways to work together and integrate cross-disciplinary experts in their efforts, with a large-scale multi-organizational structure (including academia, industry, national labs, and federal agencies) to build a roadmap with a clear science and technology charge, with an entity of authority, responsibility and accountability, building of trust, the quantum internet can become a major success story in science, technology, and society.

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