



The next 75 years: Symposium sparks upgrade to US policy model for R&D

nationalacademies.org/EndlessFrontier

At the beginning of her talk at the symposium marking the 75th anniversary of Vannevar Bush's report that shaped science policy in the United States, France Córdoba, then director of the US National Science Foundation (NSF), presented a statuette of Vannevar Bush, referring to it as the "Oscar" for science. The statuette is based on a replica of a Bush statue housed in the lobby of the NSF building.

Córdoba handed the statuette to Marcia McNutt, president of the US National Academy of Sciences, who co-sponsored the one-day symposium, "The Endless Frontier: The Next 75 Years in Science," with The Kavli Foundation and the Alfred P. Sloan Foundation in Washington, DC, on February 26, 2020.

To introduce the symposium, McNutt said, "Science as practiced today is far more

international, more collaborative, more interdisciplinary, more dependent on data and observations from novel and expensive facilities, more important to economic prosperity, and a greater driver of social change than it was when Dr. Bush laid down the roadmap for the endless frontier."

Policymakers, scientists, and CEOs from government, academia, industry, and philanthropic foundations paid respect to Bush's vision and launched discussions of what the science policy blueprint should be for the next 75 years.

Materials science fits prominently in the future of R&D

As the bedrock from which "stuff" is made, materials science fits prominently in the future of R&D. Among the NSF's "10 Big Ideas," for example, is the "Quantum Leap," which funds research

in quantum materials to revolutionize technologies such as sensors, computers, modeling, and communications (see *MRS Bulletin*, doi:10.1557/mrs.2020.76). "The endless frontier continues to be a human-technology frontier, posing ethical challenges," said Córdoba. Therefore, NSF approaches future scientific challenges "through the combination of diverse expertise," she said, that will be propelled by machine learning, artificial intelligence, the Internet of Things (IoT), and robotics.

At the symposium, L. Rafael Reif, president of the Massachusetts Institute of Technology (MIT), reiterated that artificial intelligence, machine learning, quantum science, and clean energy, as well as the next wave of telecommunications, make his short list of critical science and technology (S&T) fields. Republican US Senator Lamar Alexander said, within his introductory remarks at the symposium, that clean energy solutions is his proposed "Manhattan project." Alexander, who chairs the Subcommittee on Energy and Water Development within the Senate Committee on Appropriations, said that meeting the grand challenges for energy "would create breakthroughs, for example, in advanced nuclear reactors, natural gas, carbon capture, better batteries, greener buildings, electric vehicles, cheaper solar, and fusion." He lauded Oak Ridge National Laboratory, part of the original Manhattan Project, in his home state of Tennessee, which conducts the "most complete advanced materials research, the building block for almost every sort of technological innovation."

Data sharing at the national and international level

The massive complexity of emerging research topics, many panelists agreed, requires international cooperation to share research information as well as to collaborate on research projects. Gabriela



France Córdoba, former director of the US National Science Foundation, stands with the agency's reproduction of the Vannevar Bush statue from the collections of the National Museum of American History, Smithsonian Institution. This 3D-printed statue is made of a photosensitive resin that is cured from viscous liquid to a solid by exposure to UV light. After printing, the cured Bush statue was primed and painted with automotive paint to simulate the patina of aged bronze. Credit: Anne DuVivier for the National Science Foundation.

González of Louisiana State University and a member of the Laser Interferometer Gravitational-Wave Observatory (LIGO) Scientific Collaboration, said, “Data sharing is essential to scientific progress.” She said that researchers now tackle large projects that require sizable, multinational research teams for which students, for example, are not trained.

Kristen J. Baldwin, deputy director for strategic technology protection and exploitation at the US Department of Defense, also called for the reinforcement of a US and ally partnership in the next 75 years. She advocated for international agreements and co-sponsorship of R&D funding for megaprojects such as advanced materials for additive manufacturing, quantum science, and artificial intelligence. To make such partnerships succeed, she said the United States needs to train and educate faculty and university researchers about threats and policy expectations because faculty is accustomed to openness in research. The US Government has recently been enforcing the need for disclosures among faculty members not only for defense, but for protection of intellectual property for economic reasons.

In the next 75 years, panelists said US R&D policy needs to balance the risks of national and economic threats with the necessity of international openness. Sharing information globally has particularly shown its importance during the novel coronavirus COVID-19 pandemic. Materials researcher Robert Langer, who is the David H. Koch Institute Professor at the Massachusetts Institute of Technology, has benefited from open data in his work on developing a vaccine for the virus. According to the timeline given by a company Langer co-founded, Moderna, Inc., researchers in China uploaded the genetic sequence of the novel coronavirus to a public database on January 11, 2020, and within two days, the research team at Moderna, together with the National Institutes of Health (NIH), finalized the sequence for mRNA-1273, which is now the basis for the company’s lipid nanoparticle-based vaccine. The mRNA is taken to immune cells where it instructs cells to synthesize the spike protein as if they have been infected by COVID-19. By



Marcia McNutt, president of the US National Academy of Sciences and co-sponsor of the Endless Frontier symposium “The Endless Frontier: The Next 75 Years in Science,” with The Kavli Foundation and the Alfred P. Sloan Foundation in Washington, DC, on February 26, 2020, gives the opening address. Credit: Karen Sayre, Eikon Photography.

March 16, the Phase 1 study for mRNA-1273 had begun.

For treating COVID-19, however, Thomas Webster, the Art Zafriropoulo Chair in Engineering at Northeastern University, pointed to the general lack of an immediate international roadmap for sharing data. He works with nanoparticles to simultaneously diagnose and treat various diseases, a new medical field called theranostics. In order to develop nanoparticles to attach to and disrupt the COVID-19 virus’ ability to replicate, his laboratory needed to know quickly the numerous mutation structures of the virus. However, he was unable to obtain information instantly from the US Centers for Disease Control (CDC) and found no early portal on the CDC website with information concerning the numerous COVID-19 mutations that were being reported from around the world. Further mutation structures are now known through scientific publications, but because of delays in the traditional publication process, Webster was frustrated with the lack of immediate availability of such data and points to a general flaw in the research process both nationally and internationally.

Nationally, he told *MRS Bulletin*, the various US agencies that fund individual research groups seem to have had no coordination when this pandemic started or even now with one another, internationally

with other funding agencies, universities, national laboratories, and industry that could enhance COVID-19 research. For example, Webster said, for COVID-19 research, federal agencies could say, “Once funded, this is the lab that you could contact to test your materials, or these are the people who have authorization to deal with COVID-19 who can see if your material is effective.” Pandemics such as COVID-19 will continue to occur, Webster said, and they will need to be better solved by breaking the funding silos at the international and national levels.

Models of community involvement necessary for scientific R&D

More than cooperation across borders, Gabriela González said at the symposium, “[We] get the best science done with diversified people.” Diverse demographics is a major priority within NSF, too. Among the 10 Big Ideas formulated and pursued by NSF is inclusion, Córdova said. “We know that having a diversity of voices and perspectives enables us to make greater progress,” she said.

González went beyond a diversified community of scientists, however. She advocated placing patients, for example, to sit on review committees to align scientific research with patient priorities. The Bill & Melinda Gates Foundation, known

for funding research to improve global health, has consistently put patients at the center. Several years ago, the Foundation approached Robert Langer to develop an ingestible, long-lasting, drug delivery device. The purpose is to enable patients who have difficulty reaching medical clinics or affording medications, particularly in developing countries, to receive adequate medication.

In response, Langer's research group developed a device constructed from gel polycaprolactone (PCL), a nontoxic, degradable polyester that can reside in the stomach long enough to release medication for over a week before dissolving. The device is shaped like a star in which the arms hold the medication, but the body of the capsule does not serve as an obstruction in the stomach. Langer told *MRS Bulletin* that the pill is also useful, in general, for the 50% of patients worldwide who forget to take their daily medication.

At the symposium, Shobita Parthasarathy, professor of public policy at the University of Michigan, said citizens feel they have no voice about the direction of science and technology, which leads them to distrust scientists. For example, the status of public health shows that segments of the community have been marginalized, she said. Social context needs to be integrated into research funding and regulatory decisions.

Science writer and materials scientist Ainissa Ramirez agrees. But before that can happen, Ramirez told *MRS Bulletin*, "the general population is going to have to be educated so that they know more about science and feel comfortable asking questions and know that science isn't always about having the answers." And scientists, she said, have to be educated to listen.

While writing her book *The Alchemy of Us*—which was recently released—Ramirez became far more aware of the unintended results of science on society. For example, she looked into the invention of the incandescent light bulb, since she was interested in the materials that went into it. From discussions with physicians and medical researchers, however, she learned that artificial light puts people's bodies into constant "daytime" mode, which leads to a number of health ailments,



Actor Alan Alda gives the keynote talk coupled with a demonstration showing how to engage the public in a conversation about science. In the background (left to right): Cristin Dorgelo, president and CEO of the Association of Science and Technology Centers and Elizabeth Christopherson, president and CEO of Rita Allen Foundation. Credit: Karen Sayre, Eikon Photography.

a side effect of the easy availability of light at all times (see the book review in *MRS Bulletin*, doi:10.1557/mrs.2020.110).

The symposium brought in actor Alan Alda, founder of the Alda Communication Training Company, to give the keynote talk about science engagement with the public. While his work has centered on training researchers to communicate their enthusiasm for science in a way the general population can understand, his demonstration at this symposium went beyond that. "When science is looking for funding," Alda said, "there are biases in the culture that can form resistance." Alda said he is talking not just about clarifying scientific terms, but engaging people. In order to develop their "message," researchers need to establish a personal connection with the audience, and training in improvisation exercises—similar to the performance of actors without a script—can accomplish this. Alda said scientists actually need to "use the connection that they develop with the audience to formulate the message, so the message is not just based on what's in their head. The message is based on something that they understand about the audience ... what they're thinking and feeling."

Ramirez discovered that a way of making connections is through stories. She realized that for years she had been explaining

science to people to make them scientists. "But," she told *MRS Bulletin*, "I wanted to bring more people to the table, and I know that stories are stickier than just explaining data and explaining phenomena."

Scientists need to translate their research not only to the public, but also to one another, Alda said. For example, with the NIH Brain Initiative aimed at revolutionizing scientific understanding of the human brain, collaboration between neuroscientists and nanoscientists will not only improve with better communication, but explaining their work to colleagues in another field will help them "understand their own work even better," Alda said.

In addition to seating patients at the table, panelists illustrated other ways of including society in scientific research planning. Mahmud Farooque, Arizona State University and associate director of the Consortium for Science, Policy & Outcomes in Washington, DC, said when researchers go to society, "the conversation changes." Regarding autonomous vehicles, while researchers may be thinking of vehicle safety, first responders wanted to know how to rescue passengers from such a vehicle, and drivers expressed their desire for "assistance" from the vehicle rather than a fully autonomous vehicle.

A long-term research project on sustainability underway at the University of California, Davis (UC-Davis) includes studies on autonomous vehicles. A year ago, the university announced its experiment of an automated, all-electric shuttle placed in its sustainable community called West Village. According to the university's news release, "We want to see how residents respond to the vehicle before and after their experience with it to see if there are attitudinal changes," said Yunshi Wang, director of the UC-Davis China Center for Energy and Transportation. "We'd like to better understand how people embrace or resist vehicles like this and their potential to help with ride sharing or carpooling," Wang said.

In a report submitted to the Public Utilities Commission of the State of California this year, the university presented necessary changes to its pilot test for a shared autonomous vehicle program. "The areas for improvement in the existing framework include fares, fare-splitting, pooling, data collection, ensuring service for people with disabilities, ensuring service to disadvantaged areas, and service to airports." Indeed, the report recognizes that the "convergence of new shared mobility services with automated and electric vehicles promises to significantly reshape our lives and communities." UC-Davis demonstrates how various institutions have already been moving in the direction of public-centered research that embraces stakeholders from different sectors of society.

At the symposium, Cristin Dorgelo, president and CEO of the Association of Science and Technology Centers and former chief of staff at the White House Office of Science and Technology Policy during the Obama administration, offered several ways to engage the public, beginning with "transparency." Dorgelo also referred to the Brain Initiative as an example, where researchers have to explain a 10-year R&D agenda to a society that wants to urgently cure diseases. By engaging the public with the ethical issues involved in the Brain Initiative, researchers involve the public in the process of the research, she said.

David P. Norton, who chairs the Government Affairs Committee of the Materials Research Society, told *MRS Bulletin*, "We talk about materials research as if it were a defined linear process where specific targets of our work are well defined but with long, excruciating timelines. That is, in fact, not how it actually works." He said that basic research builds a broad, diverse foundation of knowledge that offers opportunities that are often unforeseen, and the public needs to see the value of that. The COVID-19 pandemic, he said, serves as a perfect illustration.

As vice president of research at the University of Florida (UF), Norton is well versed in the advantages of multidisciplinary work in research laboratories across the campus. UF virologist John Lednicky has been studying viruses in wildlife for more than 35 years, including coronaviruses

found in bats. "Little did Dr. Lednicky realize that the basic research he was doing years back on coronavirus in animals would become the most critical scientific and medical challenge of this century," Norton said as Lednicky is now applying his work to detect COVID-19 in humans. "The value of basic research is found in the knowledge it provides for future challenges, some predictable, others unimaginable," Norton said.

The role of philanthropy in scientific R&D

Philanthropists know well the benefits of public-centered endeavors, as well as financing high-risk research. When discussing the science enterprise at the symposium, Mary Woolley, president of Research!America, included civil society and "the business community that also fuels research and, in the process—and in many wonderful cases—has created great wealth. We're all in it together." Woolley's organization builds a strong base of citizen support for medical research and innovation.

In a panel on philanthropy, the president of Rensselaer Polytechnic Institute, Shirley Ann Jackson, pointed to the support philanthropists have given to early research ideas that were unable to garner federal funding, to infrastructure within universities that would not exist otherwise, and to partnerships across university departments and with corporations. Jackson said, "Foundations many times just inherently support new directions and risk-taking."

In the same panel, president of the Carnegie Institution for Science, Eric D. Isaacs, reinforced that philanthropy supports unconventional, revolutionary ideas and enables scientists to focus entirely on their research. Robert Langer, with support from the Gates Foundation, founded Lyndra Therapeutics, Inc. with its revolutionary idea of changing the method of drug delivery instead of trying to change human behavior. Among the benefits of receiving funding from the Foundation, Langer said, is his ability to see the impact of his work on the patient. With its focus on a practical mission, the Gates Foundation is proactive as it continues to fund Langer's research, he said. The Foundation, Langer told *MRS Bulletin*, is eager to move research forward. This resulted in



(Left to right): Adam F. Falk, president of the Alfred P. Sloan Foundation and co-sponsor of the symposium; Mary Woolley, president of Research!America; and Eric D. Isaacs, president of the Carnegie Institution for Science talk about the revolutionary work Foundations enable. Credit: Karen Sayre, Eikon Photography.



multimillion-dollar grants to Lyndra as the researchers developed its capsule platform capable of treating numerous diseases.

Adam F. Falk, president of the Alfred P. Sloan Foundation, which co-sponsored the symposium, said that what makes philanthropy-based science distinctive from other sources is its higher tolerance for risk, thus high tolerance for failure. Foundations, he said, are not responsible for supporting the entire enterprise, but can focus on emerging areas, interdisciplinary projects, and young researchers, and they are free from answering to complicated legal environments.

Small pockets of government funding programs involve high risk, and more and more government programs fund multidisciplinary research teams. US Senator Chris Van Hollen, Democrat, representing the state of Maryland, who serves on the Senate Appropriations Committee, referred to the success of the government high-risk funding agency, Advanced Research Projects Agency-Energy or ARPA-E. The projects supported by this agency, he said in his remarks at the symposium, “have improved our solar panels, our electric car batteries, and many other inventions that have reduced our reliance on fossil fuels ... and helped keep the United States competitive in high-growth economic sectors.” But, he said, the government needs a new strategy to maintain its technological edge. Panelist Ronald Daniels, president of Johns Hopkins University, said the government needs to identify what “mechanism of philanthropy should be emulated and find its way into the federal funding system.”

Paradigm shift needed in industry and higher education

Norman R. Augustine, retired chair and CEO of Lockheed Martin Corporation, said the average stockholder used to hold shares for eight years, but now they will hold a share for four months. The



Audience members ask questions during The Endless Frontier: The Next 75 Years in Science Symposium at the National Academy of Sciences, February 26, 2020. Credit: Karen Sayre, Eikon Photography.

unintended consequence is short-term research by industry. Augustine told the audience that a paradigm shift needs to include “intermediate organizations to move innovations into industry that can apply them.” Rafael Reif had also said, near the opening of the symposium, that the current system of venture capitalism forces researchers to try to commercialize their inventions too soon. He said the science enterprise needs to “experiment with novel ways to help entrepreneurs get their ideas to market faster.”

Panelists called for a shift in the advanced educational system as well. Laurie Leshin, president of Worcester Polytechnic Institute (WPI), promoted an educational system that makes R&D relevant. Students at WPI, for example, have to work on problems that “intersect with science, technology, and the world,” Leshin said.

With the launch of a nonprofit higher education institution called Station1 (station1.org), founders Morris Cohen Professor of Materials Science and Engineering Christine Ortiz and Historian of Science and Technology, Ellan Spero,

both at MIT, have developed an institution that is based on a newly developed model of inclusive and socially driven science and technology education, research, and innovation. With a custom-designed learning space and residential apartments based in a historic mill in Lawrence, Mass., students come from across the country and the world to participate in an all-expenses paid fellowship that involves a unique cross-disciplinary curriculum on socially directed STEM integrated with undergraduate research internships in emerging STEM fields.

“Reforms of STEM education,” Ortiz told *MRS Bulletin*, “will need to go beyond surface structural and incremental changes.” She said, “Given the current healthcare crisis and the amplification of inequities in our higher education system, we are observing a shift from a mind-set of recovery to reconstruction and redesign, in particular at the intersection of equity and resiliency.”

The February symposium, reported the National Academies, “marked the start of a year-long conversation.”

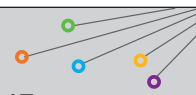
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EU and Thailand address bio-circular-green-economy

To lead Thailand into a highly developed economy that leaves no one behind, the Thai Government has introduced a bio-circular-green economy (BCG) as its new economic model. BCG includes the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products, and bioenergy.

The Thai Government expects that by adopting the BCG model for economic development, Thailand can raise its GDP by 1 trillion Thai Baht within the next five years and support 20 million jobs in the four industrial sectors targeted by BCG—namely Food and Agriculture; Medical and Wellness; Energy, Material and Biochemical; and Tourism and Creative Economy.

To achieve this goal, H.E. Suvit Maesincee, Thai Minister of Higher Education, Science, Research and Innovation, says “new knowledge and technology must be used to add more value to more products

from various sectors, including food and beverage manufacturing, medicine, energy, biochemicals and tourism.” Maesincee led a Thai delegation to participate in a Roundtable Discussion with the EU in January, hosted by Pirkka Tapiola, Ambassador of the European Union to Thailand, along with ambassadors and trade attachés from a number of EU member countries. The Minister was joined by the President of Thailand’s National Science and Technology Development Agency (NSTDA), Narong Sirilertworakul and a number of NSTDA executives.

Tapiola said that the “EU has placed the European Green deal at the heart of its policies. It is an opportunity to improve the health and well-being of people by transforming our economic model. We want to cooperate with our partners so that the principles of the green deal can be promoted globally.” The EU has already adopted a Circular Economy package covering the whole cycle: production, consumption,

waste management, and secondary raw materials, and for the past two years has invested close to 1 billion Euro (33 billion Thai Baht) into research and innovation as well as financing projects and initiatives to support this strategy.

During the event, Maesincee gave a presentation on the BCG model for sustainable development, which was followed by a presentation by NSTDA outlining its research program and infrastructure that support BCG, including the progress of the Eastern Economic Corridor of Innovation (EECi) construction. EECi is a new innovation zone situated on 1200 acres of land adjacent to the Eastern Economic Corridor—which encompasses three Eastern provinces of the country—to serve as Thailand’s new growth hub. It will house state-of-the-art essential facilities for bioindustry development such as a plant factory, phenomics greenhouse, and biorefinery pilot plant as well as advanced infrastructure such as a Demo Factory and Industry 4.0 Testbed, fourth generation Synchrotron Facility, an Autonomous Vehicle Testing and Living Laboratory and High Performance Computing Facility.

New call issued for joint Canada-UK projects on quantum technologies canada-uk-quantum-technologies.b2match.io/home

The Natural Sciences and Engineering Research Council of Canada (NSERC) and Innovate UK, part of UK Research and Innovation, are partnering to launch a call for research proposals on quantum technologies. The call builds on complementary interests and research expertise in this area in the UK and Canada, and will allow for the collaboration between leading-edge scientists and potential users from industry and/

or government sectors to accelerate the development of quantum technologies.

Innovation in quantum technologies would allow Canada and the UK to access cross-cutting technologies and to function securely in a global ecosystem where the safe exchange and protection of data is paramount. It also aims to bring together dynamic consortia that will foster collaboration between established researchers and the next generation

of young scientists in partnership with industry and/or government. According to NSERC, this will help break down silos among disciplines and promote equity, diversity, and inclusion. The research in these collaborations will provide demonstrable evidence of the impacts of quantum technologies for the economy and society.

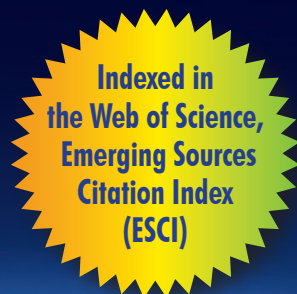
Applicants and participants may register and create a profile in order to access a virtual matchmaking website, which will allow them to select and contact potential partners from both countries for information exchange and networking opportunities to foster collaborations. □

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