



Public Meeting of the  
President's Council of Advisors on Science and Technology (PCAST)

November 1, 2024

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## Meeting Minutes

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### MEETING PARTICIPANTS

#### PCAST MEMBERS

- |                              |                          |                       |
|------------------------------|--------------------------|-----------------------|
| 1. Frances Arnold, Co-Chair  | 10. Sue Desmond-Hellmann | 19. Saul Perlmutter   |
| 2. Arati Prabhakar, Co-Chair | 11. Inez Fung            | 20. William Press     |
| 3. Maria T. Zuber, Co-Chair  | 12. Andrea Goldsmith     | 21. Jennifer Richeson |
| 4. Dan E. Arvizu             | 13. Laura H. Greene      | 22. Vicki Sato        |
| 5. Dennis Assanis            | 14. Paula Hammond        | 23. Lisa Su           |
| 6. John Banovetz             | 15. Eric Horvitz         | 24. Kathryn Sullivan  |
| 7. Lisa A. Cooper            | 16. Joe Kiani            | 25. Terence Tao       |
| 8. John O. Dabiri            | 17. Jon Levin            | 26. Phil Venables     |
| 9. William Dally             | 18. Steve Pacala         | 27. Catherine Woteki  |

#### PCAST STAFF

1. Lara Campbell, Executive Director
2. Melissa A. Edwards, Deputy Executive Director
3. Bich-Thuy (Twee) Sim, Assistant Director for Transformative Medicine and Health Innovation
4. Sachin Shah, Policy Analyst
5. Kelli Moore, Policy Analyst

**START DATE AND TIME:** Friday, November 1, 2024, 10:00 AM EASTERN TIME

**LOCATION:** National Academy of Sciences and Livestreamed via Zoom.gov

## WELCOME

### **PCAST Co-chairs: Frances Arnold, Arati Prabhakar, Maria Zuber**

The PCAST co-chairs called the meeting to order – Frances Arnold, California Institute of Technology; Arati Prabhakar, Science Advisor to the President; and Maria Zuber, Massachusetts Institute of Technology. Zuber noted that Frances Colón had resigned from PCAST as of October 7, 2024 and acknowledged the significant contributions she made to PCAST and her historic role as the first Hispanic woman named to PCAST.

### **SESSION: DISCUSSION AND CONSIDERATION FOR APPROVAL OF PCAST LETTER TO THE PRESIDENT ON THE VALUE AND IMPORTANCE OF FEDERAL RESEARCH AND DEVELOPMENT**

Zuber noted the high quality of life and vibrant U.S. economic prosperity is built on federal research and development (R&D), which contributes to health advances, addressing climate change, national security, workforce development, economic growth, and opportunity for all Americans. U.S. R&D funding—approximately 3.5 percent of U.S. gross domestic product—is spread across both the public and private sectors. However, she added, the private sector drives this impressive level of spending, which speaks well to the strength of the nation's private sector. At the same time, U.S. private-sector R&D builds on prior federal investments.

Federal investments, said Zuber, benefit industry in multiple ways. It is the basis for stimulating new ideas, developing new products and services, assessing and managing risks, and educating workers who receive their training in university laboratories overwhelmingly funded by federal R&D expenditures. Federal R&D is also critical for supporting public missions and public responsibilities in national security, health, clean energy and assessing and addressing the climate crisis, and space exploration. In addition, federal R&D is the primary driver of expanding the frontiers of knowledge upon which the nation's R&D efforts depend.

Zuber noted the Biden-Harris administration has been a champion of federal R&D spending. From fiscal year (FY) 2021 to FY 2023, federal R&D funding increased from \$16 billion FY21 to \$200 billion FY23. This expansion included new investments to address new needs, such as establishing the Advanced Research Projects Agency for Health (ARPA-H) and the Directorate for Technology, Innovation, and Partnerships at the National Science Foundation (NSF). It also expanded R&D to address key national priorities, such as \$11 billion for semiconductor R&D in the CHIPS and Science Act and funds in the Inflation Reduction Act for clean energy R&D.

However, said Zuber, budget caps stalled federally funded R&D at \$200 billion in FY2024, with non-defense R&D falling approximately 10 percent from \$101 billion in FY23 to an estimated \$91 billion in FY24. This reduction triggered cuts across federal science agencies, including NSF, the National Institute of Standards and Technology, National Aeronautics and Space Administration, and National Oceanographic and Atmospheric Administration. Budget caps also constrained the President's budget request for FY25 to \$202 billion.

Nonetheless, said Zuber, an encouraging sign is the bipartisan group of Senators calling for significant R&D growth. The Bipartisan Senate Artificial Intelligence (AI) Working Group is calling for \$32 billion in annual

non-defense AI R&D, including broad federal R&D as necessary to support U.S. AI leadership by funding the “Science” part of the CHIPS and Science Act that are not yet fully appropriated. PCAST, she added, is in a good position to advocate for this because it has discussed AI’s role with the President on multiple occasions and written a report about the importance of AI for future discovery.

Zuber summarized the letter to the President as asking the administration to prioritize federal R&D funding in negotiations with Congress on FY25 appropriations. The letter also encourages the administration to identify other legislative opportunities for investing in R&D. The importance of public R&D funding to the nation must not be neglected in the press of urgent concerns, she said.

After Zuber’s presentation, discussion among PCAST members followed.

#### **ZUBER MODERATED THE Q&A AND DISCUSSION WITH PCAST MEMBERS.**

William Dally said the letter should emphasize national competitiveness, particularly given China’s heavy investment in R&D. This investment comes with the risk that China could surpass the United States and become the leader in science and technology unless the United States invests in the future. He also recommended connecting the dots between federal R&D and industrial R&D and prosperity. He noted that most industrial spending in R&D goes toward development, a large portion of which previous federal R&D enables. It is important to keep the pipeline full, he said, where federal spending on research leads to industrial spending on development and prosperity for everybody in the United States.

To make the idea more concrete, Saul Perlmutter suggested making it clear that there is a balance between investments on the research side and the outcome on the industry side. He suggested providing examples where basic research led to great advances, such as the global position system, mRNA vaccines, and AI, and then imagining what the next exciting advancement might be. For example, what might U.S. investing in quantum computing lead to, including the out-migration of talent, compared to if Europe or China invested heavily in that area.

Eric Horvitz also called for emphasizing the complementarity between industrial and federal R&D and to note that industry cannot be expected to make up for any reduction in federal funding of basic research and the potential gains that come from open, multi-year curiosity-driven research. This is a critical time where AI and biology and space, physics, and chemistry, for example, are coming together in new ways. He also pointed to the important role federal R&D spending plays in workforce training, and particularly in training people who can think outside the box.

John Banovetz said the letter needs to stress the effect of federal R&D on economic prosperity. He also reiterated the importance of the federal R&D budget for expanding the frontiers of knowledge and how that pushes companies forward into new areas. In addition, there are collaborations and connections between industry, academia, the national laboratories, and others that do not happen without federal R&D. Federal R&D also helps de-risk opportunities for industry providing a long-term catalyst for the health of the national economy.

Andrea Goldsmith pointed out that federal investment in basic R&D has been critical for the nation to attract and retain the best minds from around the world in science and technology. This investment has not only drawn talent to explore curiosity-driven research, but is an important contributor to the nation’s entrepreneurial ecosystem and keeping it vibrant.

Frances Arnold agreed with Goldsmith and noted that basic research is what starts the innovation cycle and creates whole new industries. That cycle of innovation will not continue without continued federal support for basic research, and the letter to the President should point that out, she added.

Paula Hammond noted that exploratory research and even more applied research that federal funding supports is critical for workforce training at interdisciplinary interfaces, which is where the growth of science and technology is happening today. She thought it would be interesting for the letter to include data on the number of trainees associated with grants over a given period. These are trainees that go to industry with new skill sets and that help grow fields critical to national growth.

John Dabiri also stressed the important role federal R&D funds play in training the next generation of talent that is vital to industry.

William Press said this letter addresses an issue that carries over to future administrations and that is largely, if not completely, a bipartisan issue.

Jennifer Richeson mentioned that another important role federal R&D funding plays is in soliciting proposals from across the nation, including places that might not have a company that is innovating and doing R&D in the private sector. In that way, federal investments in R&D help find individuals and ideas that are often overlooked, and that is something that industry-funded R&D cannot replace.

Jon Levin added this is an important time for the federal government to invest in R&D given the increasing international competition for scientific talent and the importance of the United States retaining its scientific leadership. In particular, he added, this is a period of great opportunity with advances in machine learning and AI that will accelerate scientific discovery across a range of disciplines, so the return on investment today is likely to be high.

Dan Arvizu said other countries, including China and those in Europe, are making huge investments in discovery science. Since U.S. researchers cannot participate in endeavors funded by other federal governments, the United States needs to support its ecosystem and future science and technology workers.

Catherine Woteki pointed out there are areas of science the letter notes in which China's investment already greatly exceeds U.S. investment. Agricultural research is one such area, and it has big implications for the public good agenda the letter emphasizes. Woteki posed using seed corn as a metaphor for the importance of federal R&D investments and suggested calling out other areas in which U.S. competitiveness is eroding. Zuber added that China has stated it will increase its R&D investment by 10 percent next year.

Dennis Assanis echoed his colleagues' support for preparing this letter, both to thank the President for the wonderful work he has done over his tenure and to remind other readers in the United States who should support federal R&D funding. He reiterated that industry funding cannot compensate for a decrease in federal R&D funding. He emphasized that some of the most successful stories are those involving consortia with federal, industry, and university partnerships, such as developing manufacturing processes of new biopharmaceuticals to treat cancer, innovations in clean energy, and reaping the synergies in interdisciplinary areas to address neurological disorders.

Laura Greene said China's funding to discover new materials that might be used for future sensors and other applications has surpassed that of the United States.

Vicki Sato noted that U.S. leadership in biomedical research, which has contributed to the health and welfare of Americans, is being threatened, and sometimes, surpassed. This, she said, reflects how essential continued momentum and investment in basic research is for translating innovation into economically meaningful advances.

Terence Tao agreed about the importance of federal R&D funding for attracting leading talent to the United States. He also noted that federal funding not only spurs private-sector investment, but research funded by nonprofits and philanthropy. Federal funding in that way is a multiplier that can attract other sources of funding.

With the discussion concluded, PCAST voted unanimously to accept the letter. Zuber said it will be published and shared with the President in the coming weeks after editing it to reflect the important comments made during the discussion.

#### **SESSION: DISCUSSION AND CONSIDERATION FOR APPROVAL OF PCAST REPORT TO THE PRESIDENT ON A REVIEW OF THE NETWORKING AND INFORMATION TECHNOLOGY R&D PROGRAM**

This report, said Arnold, reviews a federal program that provides a coordinated approach to managing networking and information technology (IT) R&D activities funded by the federal government but largely performed by academic, nonprofit, and private-sector research organizations. Since 2005, the President has designated PCAST to conduct an independent review of this program every three years. She then introduced Press and Perlmutter, co-leaders of this review.

##### **WILLIAM PRESS**

The Networking and IT R&D Program (NITRD), said Press, was created by a piece of legislation in the 1990s with some unique characteristics. First, NITRD does not depend on annual appropriations because it is a coordinated effort among multiple agencies that chose to contribute their own funds to the program. Second, the program has no sunset date. Thus, NITRD is a budget roll-up to benefit each administration as it determines how key agencies are spending money on networking and IT R&D. In addition, it provides a convening opportunity through its National Coordination Office (NCO) with a subcommittee of the National Science and Technology Council (NSTC) and its representatives from several dozen federal agencies.

Press said when the PCAST working group started its review, it was skeptical that a 30-year program with no sunset clause could remain fresh and useful. What changed the working group's mind was talking to people in the federal government who value the program and find it useful. He noted that five agencies—the Departments of Energy (DOE), Department of Defense, the National Institutes of Health (NIH), NSF, and the Defense Advanced Research Projects Administration, provide most of the budget attributed to NITRD program component areas (PCAs). NSF, for example, supports research on AI, while DOE is noteworthy for its support of high-capability computing infrastructure. NIH has the largest budget roll-up into NITRD, with major support for large-scale data management and analysis.

The working group's first finding, said Press, is that NITRD continues to be useful and cost-effective in that the actual cost of the program is small. The working group made several findings and recommendations to improve the NITRD program as the first finding indicates that it is a useful and cost-effective program.

Press said the second finding was that the NCO's communication strategy, its products and their cadence, are not always well matched to the existing or potential customer base therefore the first recommendation is that the NCO should undertake a structured review of its existing report products to improve the cadence and level of detail to better match the needs of current and prospective customers, the federal officials across a wide range of government agencies. Press said the third finding—the NCO has over time become too narrow in its outreach—is not about the number of agencies NITRD is reaching but in terms of the number of officials in those agencies who would benefit from NITRD's work. Thus, the working group's fourth finding is that NITRD and the NCO are missing opportunities to:

- Provide meaningful benefit to a broader customer base of federal officials, including those in the budgeting process and those making informed technology acquisition decisions.
- Connect a broader set of stakeholders from academia and industry to NITRD R&D efforts.
- Serve as a resource and institutional memory—including across agencies and administrations—for a broader range of customers and programs than at present.

The working group's second recommendation, said Press, is for NITRD NCO to: construct and execute a multi-pronged plan aimed at expanding its customer base by identifying current customers and surveying them as to how NITRD's convenings and written products can meet their needs more effectively; contact potential new customers and stakeholders, educate them about NITRD, and explore how existing or new NITRD products might help them with their responsibilities; and identify appropriate metrics for success, such as requests for information and meetings and visits to the NITRD website. In the same vein, the working group's third recommendation is for NCO to develop a list of convenings, such as councils and committees, of federal agency officials in the areas of information and data science and technology and to assess where NITRD might contribute present and future institutional memory and R&D perspective by being, even silently, in the room. NITRD should also contact those activities and propose mutually beneficial interactions.

Press said it is good that the PCAs have constancy because it allows for longitudinal tracking for how funding varies in these areas. However, the working group felt on balance that it would be a good time to refresh the PCAs, and the fifth and sixth findings address that. The fifth finding states that the inherent inertia of the interagency process leads to PCAs that more resemble the state-of-the-art in IT a decade ago than what would today best serve the purposes of the NITRD Program's authorizing legislation as forward-looking guidance. Therefore, the fourth recommendation is that NITRD NCO should use its statutory authority to undertake a zero-base refresh of the PCAs. New PCAs should be future looking and aim to encourage R&D by agencies on and using today's and tomorrow's most relevant technologies. NITRD NCO should also aim to make the PCAs more useful as budget-reporting categories for policymakers.

The sixth finding, said Press, is that budget reporting via the PCAs could be made more meaningful by additional binning into uses of different character. The accompanying fifth recommendation called for agencies' budget reporting against the PCAs should, for each PCA, give the breakdown in its dollar amount into four bins. Press acknowledged this recommendation makes more work for the agencies.

Nevertheless, the working group felt this roll-up would be more informative if the agencies reported in these four bins:

1. R&D on the PCA, such as advancement of that PCA as a subfield of information and data science and technology.
2. R&D using that PCA to advance the agency's mission.
3. Infrastructure investment, exclusive of operating expenses, that support that PCA.
4. Infrastructure operational expenses that support that PCA.

Press said the working group found the NSTC NITRD interagency working groups to be valuable, the seventh finding. They would, however, benefit from greater flexibility in their number, definitions, and lifetimes, more like the present NSTC Fast Track Action Committees and Communities of Practice and less tied, even if only implicitly, to the PCAs. This would also enable NITRD to give the PCAs more strategic and modern definitions. The accompanying sixth recommendation calls for NITRD NCO and NSTC NITRD subcommittee to clearly separate the organization of their convening activities from the definitions of the PCAs. In addition, the number, definitions, and lifetimes of all the convenings should be flexible, variable, and customer-driven.

The eighth and ninth final findings address AI specifically, said Press. Finding 8 holds that AI's long-term societal significance may be comparable to the invention of the internet and larger than high-performance computing was initially, the original impetus for founding NITRD. Finding 9 states an opportunity exists for NITRD to contribute to, and sometimes lead, activities being undertaken government-wide in response to the AI Executive Order. The accompanying seventh and final recommendation calls for NITRD activities to more specifically address the "special moment of AI." NITRD should reach out to, and increase its involvement with and usefulness to, the many new federal activities in AI.

After Press's presentation, discussion among PCAST members followed.

#### **ARNOLD MODERATED THE Q&A AND DISCUSSION BETWEEN PCAST MEMBERS AND PRESS AND PERLMUTTER**

Perlmutter said the working group hoped that enacting these recommendations would be a stimulating opportunity for the NCO and NITRD to do something more than they are currently doing.

Dally, a member of the working group, added this is an opportunity for NITRD NCO to broaden its reach, redefine the PCAs to be more relevant, and be a bigger part of AI.

Arnold asked who uses the data from the budget roll-up and why reporting spending is important. Press replied that the Office of Science and Technology Policy (OSTP) uses the roll-up as input for its structuring of the federal budget. He explained that NIH's support for NITRD is distributed among tens of thousands of individual research projects, and anyone involved in budgeting might ask how much of that is supporting national priorities in networking and IT R&D. He sensed that these data are used by Congress and in presenting the President's budget to Congress. Perlmutter added that a policymaker hoping that R&D was moving one of the sub-areas forward and who saw there was funding there might not know the money going toward existing developments. They would not realize there is a missing ingredient in the budget to push things forward.

Prabhakar noted that she uses NITRD data. Those data, she said, played a role in the bipartisan Senate group's goal of putting \$32 billion in non-defense AI R&D, which Zuber noted earlier. She



also supported the specific call-out regarding AI in the findings and recommendations. She noted, too, that the NITRD team is pulling together data on federally funded AI R&D to help OSTP envision what federally funded AI R&D would look like at full scale regarding compute and data infrastructure and applications.

When Arnold commented that the customer should be telling NITRD what the important PCAs should be, Press replied that a large part of the customer voice comes through the representatives on the NSTC subcommittee. However, they are also a voice for maintaining continuity in the PCAs, so there is a tension there.

Horvitz, who was a member of a previous NITRD review working group and later a customer for NITRD data, said the current report and its recommendations differ significantly from 12 years ago. He endorsed and was enthusiastic about the current report's findings and recommendations to introduce robustness, flexibility, and adaptability to the way NITRD works.

Zuber expressed concern that the recommendations will increase the bureaucracy and asked if the other recommendations will simplify agency tasks. Press replied that NIH, for example, uses AI to prepare its roll-up by inputting information on all of its research proposals. Aside from the role AI can play in reducing agency demands, the working group did not develop explicit recommendations for reducing bureaucracy. However, this is a small program and the recommendations do not call for expanding staff level. The working group asked the NCO to study the best way to accomplish these goals, and the NCO does not want to make more work for the agencies.

Goldsmith, noting one of the PCAs is on advanced communication technologies, asked if the waning of the national investment in those two areas over the last decade or two has put the nation at a competitive disadvantage related to China and if the PCAs could have better identified that issue. Press replied that he would not characterize wireless technology or quantum computing as failing to appear in previous PCAs, but her question is an example of what a zero-based examination of the PCAs would identify.

Goldsmith also asked if similar mechanisms exist for other areas such as human health or perhaps quantum computing in its own right. Prabhakar said NSTC and its myriad components does exactly that across all areas of R&D. Something similar to NITRD has existed and flourished for every area of federal R&D since the Clinton administration.

Hammond asked what happened when there are areas of research that intersect between two PCAs. Press said the working group asked that question and the answer was that it is up to the individual agencies to decide how to parse the associated funds. Any given dollar, however, only goes into one PCA, so there is no duplication of funds in the reports.

Press noted that the working group considered adding suggested PCAs to the report. However, it realized that it takes a great deal of study to decide what the priorities should be. The people who use the PCAs should conduct that study, not PCAST, he said.

With the discussion concluded, PCAST voted unanimously to accept the report. Arnold said it will be published and shared with the President in the coming weeks after editing it to reflect the important comments made during the discussion.



**SESSION: DISCUSSION AND CONSIDERATION FOR APPROVAL OF PCAST REPORT TO THE PRESIDENT ON IMPROVING GROUNDWATER SECURITY FOR THE UNITED STATES**

In introducing this session, Prabhakar note that the federal government does not have a role in managing groundwater, as this is dealt with at the state and regional levels. For this report, the PCAST working group focused on steps the federal government can take to empower state and regional bodies with tools and resources to help them with their decision making. She then introduced the working group co-leaders, Inez Fung, Steve Pacala, and Joe Kiani.

**INEZ FUNG**

Fung reiterated that the states have primary responsibility for creating and enforcing their own laws, policies, and regulations pertaining to groundwater. As a result, the laws and regulations vary by state, with landowners owning the groundwater beneath their land in some states, while in others, groundwater is considered a common property. Adding to this complexity, regulations change, and groundwater systems vary across the country. Geology, climate, economics, the local substrate, and the crops that can grow in an area all affect groundwater availability. This decentralized regulatory system, then, allows the states to address specific challenges and opportunities under their jurisdiction.

Groundwater, Fung explained, supplies drinking water for half the U.S. population, and approximately 70 percent of groundwater is used for irrigation, making groundwater a hidden, but crucial asset. Groundwater from the U.S. West is embedded in a wide range of agricultural products transported to the rest of the nation and in agricultural commodities exported globally. Groundwater security and sustainability, therefore, is critical for food security, health, and the U.S. economy.

Fung said the working group's consultations with a wide range of experts, including via a blog to solicit public input and a July 2024 workshop in Tempe, AZ, revealed that available funds limit state and local efforts to manage groundwater. They also have limited access to groundwater models and predictions. Fung noted that the U.S. Geological Survey (USGS) has a website with data on groundwater levels and models of varying complexity, but not every region can access those models and predictions. Expert input also highlighted the lack of standardized data protocols and metrics—USGS, U.S. Department of Agriculture (USDA), and over 700 U.S. irrigation associations all generate groundwater data—which hampers data sharing and best practices. In addition, there is a shortage of a workforce skilled in groundwater science, management, and stakeholder engagement.

Native American and Tribal communities face significant groundwater security risks resulting from extraction of non-renewable resources on Tribal lands that contaminates both surface water and groundwater, said Fung. Given the Biden-Harris administration's dedication to ensuring the health, safety, and prosperity of Indigenous communities, the working group encourages the federal government to prioritize the unique needs of Tribal communities in its water governance considerations by incorporating robust frameworks, strengthening Tribal sovereignty and self-determination, recognizing established groundwater rights, providing incentives for sustainable water use, and ensuring comprehensive data collection. Fung added that engaging Tribal organizations is crucial to addressing their specific challenges and fostering collaboration and culturally sensitive solutions.

Fung noted that as advisors on science and technology, the working group focused on the science and technology aspects of groundwater and made no recommendations on regulation. The thrust of the report addresses three questions:

- How can the federal government help state and local water managers?
- What research is needed now to safeguard water security and sustainability?
- What are potential incentives the federal government can provide to promote sustainable quantity, quality, and efficiency?

The decline in groundwater quantity and quality is an urgent problem, said Fung. USGS data shows that multiple regions have depleted their groundwater supplies between 1900 and 2008 because of withdrawing more water than the recharge rate from snowmelt and precipitation. Much of U.S. groundwater, she said, is fossil water that accumulated over 100,000 or more years and cannot be replenished naturally via precipitation and snowmelt over centuries and millennia. In addition changing climate and precipitation patterns are exacerbating natural recharge constraints, while increasing demand will further deplete groundwater storage and degrade water quality. She reiterated that groundwater depletion threatens food security.

#### **STEVE PACALA**

Pacala noted that USGS's data on cumulative groundwater depletion ends in 2008 because the state, local, and private data are not accessible to conduct a national assessment. That is unacceptable for a problem of this significance, leading to the working group's first recommendation: Accelerate the development of a comprehensive repository for data and toolkits for groundwater storage, withdrawal, and recharge and spatial and temporal scales useful for water managers and users. The working group recommended establishing an interagency working group on groundwater security and sustainability (IGGSS) to guide, coordinate, and provide oversight of the data, software, and toolkits needed to conduct water accounting and prediction by local management and to mitigate the risk of water depletion.

To enhance the collection and synthesis of measurements on groundwater inventory and quality across the nation, said Pacala, the working group called for IGGSS to designate USGS as the lead agency to host all federal and non-federal data on groundwater inventory and use, to ensure common protocols and standards for groundwater monitoring and accounting, and to provide actionable information to facilitate planning and decision making. Pacala noted that it will take time to build this database and that USGS is an agency Americans trust to be the steward of unbiased groundwater information.

Pacala said this is an heroic age for groundwater modeling, and because the field is developing rapidly and the need is so great, the working group called for IGGSS to establish a national framework to coordinate hydrologic modeling with consistent approaches to incorporate surface water and groundwater. The goal of this effort would be to develop tools to enhance U.S. capacity to manage groundwater sustainably, to support water management planning decisions, and to mitigate risk of groundwater depletion.

The working group's second recommendation, said Pacala, is to establish a research program to advance technologies and strategies for safeguarding the future of groundwater supply and quality. To develop a research program for comprehensive analysis of the chemical composition of groundwater, the working group called for establishing a coordinated measurement program that deploys state-of-the-art techniques for molecular-level identification of hundreds of thousands of chemicals in water. The program

should build on existing programs at the Environmental Protection Agency (EPA), DOE, USGS, and USDA that analyze the chemical composition of water, and partner with NSF, academia, and the private sector.

Pacala noted the two additional call-outs to this recommendation. The first is to establish a national research program to advance technologies for groundwater monitoring, recharge, conservation, and reuse, as well as new water sources to reduce pressure on groundwater resources in different groundwater basins or aquifers. To achieve this, IGGSS should convene a national initiative on managed aquifer recharge (MAR) to share knowledge about design and implementation of existing MAR projects across the nation, to understand the barriers to implementation, and to share lessons learned. In addition, the working group calls for enhancing research into new cost-effective ways to deliver water to replenish aquifers. These include technologies and strategies for MAR, long-distance pipeline transport of water, and desalination, among things.

The second call-out, said Pacala, is to support research emphasizing sustainable groundwater use to enhance food security and biodiversity. USDA Agricultural Research Service and Economic Research Service should co-sponsor research programs that would provide the scientific underpinning for farm operators to adapt their operations to maintain sustainable groundwater use.

The working group's third recommendation, said Pacala, is to establish a federal incentive program and a network of groundwater engagement hubs, including Tribal Nations Groundwater Engagement Hubs, to support and assist in planning sustainable groundwater use. Each hub in the network, which would be akin to agricultural extension offices, should be tailored to the local conditions and needs, and establish easily accessible platforms for local communities to understand their groundwater resources. The idea here, said Pacala, is to disseminate information to managers who want to use it and help engage the public, letting people know, for instance, how important their water is for local agriculture also whether or not the status of the local water is declining or increasing. The hubs should also provide access to the latest research into groundwater recycling, recharge, and reuse, as well as data to support informed decision making on development, agriculture, and business expansion. The hubs in the network should share tools and strategies and lessons learned.

Pacala said the fourth recommendation is to create a competitive grants program to incentivize planning, sustainable management, and restoration of aquifers and the surface waters critical to their recharge and cleanliness. The program should be a component of the administration's America the Beautiful Initiative. IGGSS should coordinate it and the agencies that currently host incentives for groundwater management should fund the program jointly. The funding should be primarily as federal incentives for non-federal entities with the authority to manage an integrated groundwater and surface water system. The grants program would coordinate and amplify now separate federal efforts to improve the lives of people who depend on these water systems, and in so doing create state and local political momentum to continue sustainable management. An important goal of the program should be to sufficiently scale techniques such as MAR to create an unambiguous signal in groundwater levels and learn by doing so effectively.

The fifth recommendation, said Pacala, is to incorporate valuation of groundwater resources into natural capital accounting and ensure all federal cost-benefit analyses and planning integrate these estimates. The working group recognizes that the Office of Science and Technology Policy (OSTP) has developed methods to account for the value of natural capital and added groundwater into that accounting. It also endorses OSTP's use of these valuation when making decisions across the federal government.

The final recommendation, said Pacala, is to launch a comprehensive campaign to recruit, develop, and retain a workforce skilled in groundwater science, management, and stakeholder engagement. Toward that end, the working group called for all federal agencies with responsibilities for and activities in groundwater to invigorate campaigns to recruit, develop, and retain a workforce in groundwater science and management and stakeholder engagement. Partnerships with academic institutions, industry experts, and professional organizations, he noted, can help create a pipeline of well-trained professionals equipped to address current and future challenges.

Pacala ended his comments by reiterating that none of these recommendations call for the federal government to regulate state, local, and private groundwater. Rather, they are about incentives and are grounded in view that only through a comprehensive and scientifically grounded approach will it be possible to have groundwater supplies that can maintain the health and prosperity of the nation into the future.

After Fung and Pacala's presentation, discussion among PCAST members followed.

#### **PRABHAKAR MODERATED THE Q&A AND DISCUSSION BETWEEN PCAST MEMBERS AND FUNG AND PACALA**

Greene, who was a member of the working group, stressed that the recommendation on developing and using tools for measurement are not aimed at regulation but to provide incentives and to get a better understanding of what is in groundwater.

Press added this is an important distinction given that state and local regulators might otherwise view these as something the federal government is going to eventually force them to use rather than as new tools for research. Pacala noted that the working group hears that some areas of the country want tools such as these to help them better manage their resource and see them as an important source of information. The working group purposefully chose USGS to be the steward of this information because of the public's trust in this agency.

Tao asked what some incentives could be for private holders of groundwater information to share that with the federal government. Fung said ideas the working group heard were to provide tax credits for providing the data or not reducing water levels, for example. Pacala added that such incentives could apply to ongoing taxes or to sale of the land. The important point is that opt-in would be voluntary, such as providing a tax incentive for a property owner who allowed automated monitoring of a well, for example. He noted that the density of private wells is substantial, but the data are hard to get.

Lisa Cooper asked if the working group had any suggestions for how to expand the workforce. Fung replied that the field of hydrogeology is shrinking, but there is a new area of using GPS data from satellites to measure ground depression, from which to infer groundwater levels. Academic institutions could train students on these methods. Officials from EPA noted the shortage of people to analyze the data. One idea the working group heard, said Fung, is to provide tuition support for students majoring in needed areas. In terms of engaging the public, an idea the working group heard was to engage with the Boy Scouts and Girl Scouts to grow an appreciation for the value of groundwater. Pacala noted that Tucson, AZ, has a program of water use reduction and groundwater recharge that it is using as an educational tool in the city's schools to raise awareness about groundwater and its uses. One Native

American Tribe has an internship program for high school and college students to educate them about groundwater and bring that information back to their communities. The groundwater engagement hubs, he added, should find these types of examples and try to replicate them elsewhere in the country. Fung added the hubs can also provide the means for smaller communities to access modeling and data that might otherwise be unaffordable or out of reach.

Horvitz asked if there are examples that can be used to make groundwater more salient and easy to understand, both for the U.S. citizenry and political leaders. Fung replied there are many examples, one being that one gallon of groundwater equals one almond. Kansas has developed incentives that have reduced per acre water use, and California's new Sustainable Groundwater Management Act has made water a common good managed and monitored by water districts rather than individual landowners. He said everyone is aware of groundwater depletion, making the challenge one of figuring out how the federal government can help and empower state and local authorities. Pacala countered that what is known about groundwater is not widely distributed across the country or even within government. As an example, he was not aware that refillable portion of U.S. subterranean aquifers probably exceeds the capacity of the nation's surface reservoirs, suggesting that refilling aquifers may be an alternative to finding places to put new reservoirs.

Zuber asked why there is a workforce shortage, and Fung replied that much of the blame lies in the siloing of U.S. universities. For example agriculture and hydrogeology are often in two different schools. In addition, hydrogeology is not a fashionable field today, in part because students are not aware of the urgency of matter, even though they are aware of climate change as an important problem. Both Zuber and Pacala noted this is a marketing problem, then, which is the most easily solvable of all the issues here. Pacala added that he has heard that it is difficult to retain people at universities and in government because industry is hiring them.

Sato asked if there are examples of university centers of excellence in hydrogeology or if there are opportunities for new science that existing programs can foster. Fung replied there are new opportunities and that universities will establish new departments and programs as the urgency of the problem becomes known. She sees the field of using satellite data to infer groundwater status as being exciting, as is applying AI to synthesize USGS data. Prabhakar noted that the lack of a federal agency with groundwater responsibility means there is no federal source of R&D funding to attract people to the field and get universities to engage in this type of research.

Dally said he can see how incentives will work to encourage people to participate in measurement programs and studies, but he questioned how incentives can solve the real problem of groundwater drawdown. In some sense, he said, groundwater is a tragedy of the common problem, so until incentives are large enough to replace income lost from not using groundwater, they may not stop an individual from depleting an aquifer. Pacala said there is some hope that incentives can work, as evidenced by what is happening in Western Kansas, where a group of farmers came together and decided they were concerned about water availability for future generations. They imposed collective reductions with teeth that have now begun to bear fruit. Similarly, California's new law will attempt to achieve the same result.

One thing incentives can do, said Pacala, is further science-based management and help those who want to act and succeed. Success, he added, will help recruit others into solving the problem.

Dally also asked if some people will not want measurements to occur because an aquifer is contaminated and they do not want to remediate a problem. Pacala acknowledged this is likely to happen. However, research has shown that aquifers are not passive puddles of water, but that they exchange water with each other and with surface water in ways that have surprised experts in the field. He added that as chemical analysis has improved, it has become clear that the amount of polyfluoroalkyl substances (PFAS) in groundwater is substantially greater than was known and greater than levels allowed in Europe. Prabhakar noted that EPA has moved to regulate PFAS levels in drinking water that will reduce risks for hundreds of millions of Americans. Greene added that detection technologies have evolved to answer important questions about the fate of these and other chemicals in the nation's water supply.

Hammond asked what the size of an engagement group would be and how a community would operationalize one. Pacala replied that a minimal model is one that can serve as an information conduit to the scientific and technical communities and water managers in a location, of which there are not that many. Thus, a handful of people in an engagement hub for a region as large as a state would be beneficial. If there were a larger number of individuals in an engagement hub, they could serve as conduits of credible information to the public by attending public meetings, presenting the data, and explaining that the data and models are showing.

Prabhakar asked for an example of misunderstood information. Pacala replied that there is often misinformation about whether groundwater regionally is increasing or decreasing and about the existence of as-yet undiscovered fossil aquifers. Fung added that the local engagement hubs could serve as trusted local messengers.

Woteki wondered if there was a way as part of PCAST's communication strategy to link this report to the letter to the President about R&D funding to indicate this area is so important to the nation's long-term security. Prabhakar commented that the agencies that would fund this type of R&D—USDA, NSF, and USGS—likely do not have substantial budgets and that there is downward pressure on those budgets.

With the discussion concluded, PCAST voted unanimously to accept the report. Prabhakar said it will be published and shared with the President in the coming weeks after editing it to reflect the important comments made during the discussion.

#### **PUBLIC COMMENT**

No public comments were presented.

#### **CLOSING COMMENTS**

Zuber thanked the working groups for their efforts, as well as everyone else who consulted on the development of the letter and reports presented. Arnold added there are key areas where science and technology can play an important role for American resources and well-being, which these reports highlighted.

**MEETING ADJOURNED: 1:05 PM Eastern Time**

I hereby certify that, to the best of my knowledge, the foregoing minutes are accurate and complete.

Frances Arnold, Ph.D.  
Co-Chair  
President's Council of Advisors on Science and Technology

Arati Prabhakar, Ph.D.  
Co-Chair  
President's Council of Advisors on Science and Technology

Maria Zuber, Ph.D.  
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