Directorate for Engineering Advisory Committee Meeting

National Science Foundation
Alexandria, Virginia
April 17-18, 2018
Room 2030

ENG AdCom Members Present:
Dr. Darryll Pines (chair)
Dr. Tilak Agerwala
Dr. Pedro Alvarez
Dr. Gilda Barabino
Dr. Susan Butts
Dr. Curtis Carlson
Dr. Reginald DesRoches
Dr. Leah Jamieson (via WebEx)
Dr. Kenneth Lutchen
Dr. Sarah Rajala
Dr. Maxine Savitz
Dr. Gregory Washington
Dr. Yannis Yortsos (day 1 only)

ENG Senior Staff Present:
Dr. Dawn Tilbury (Assistant Director)
Dr. Filbert Bartoli
Dr. Linda Blevins
Dr. Deborah Goodings
Dr. Don Millard
Dr. Gracie Narcho
Dr. Tim Patten
Dr. Sohi Rastegar
Dr. Mihail Roco

ENG AdCom Members Absent:
Dr. Thomas Skalak
Dr. Hossein Haj-Hariri

Tuesday, April 17, 2018

The meeting convened at 12:15 p.m.

CALL TO ORDER

Dr. Darryll Pines, chairman of the NSF Directorate for Engineering (ENG) Advisory Committee (AdCom), welcomed everyone to the meeting. Members and ENG leadership introduced themselves. The members approved the minutes of the Fall 2018 meeting.

DIRECTORATE FOR ENGINEERING REPORT

Dr. Dawn Tilbury, Assistant Director for Engineering, introduced new ENG staff. She reminded the committee of NSF and ENG current and recent budgets. She summarized ENG activities among the 10 Big Ideas, areas for future NSF investment at the frontiers of science and engineering, which have offered opportunities for funding and partnerships since the last meeting. She provided examples of emerging areas such as engineering biology, disrupting operations of illicit supply networks, and real-time learning and decision-making. Dr. Tilbury described planning grants for the new generation of Engineering Research Centers and ongoing efforts to initiate an Advanced Placement course in engineering. Then, she highlighted new NSF steps to combat sexual harassment at grantee institutions.

In conclusion, she introduced the NSF strategic plan for FY 2018-2020 and discussed the context for NSF investment plans.

Discussion
Committee members discussed engineering community engagement in the NSF Big Ideas and the importance of making clear the contributions and opportunities for engineering in the Big Idea concepts and funding opportunities. For example, in Harnessing the Data Revolution, control is clearly a question for engineering. Engineering can enable many multidisciplinary activities and paradigm-shifts through convergence research. We need to address engineering contributions in our story and share it widely. The ENG visioning activity will help as will the democratization of engineering.

NSF BUDGET UPDATE

Mr. Antony DiGiovanni, acting Division Director of the NSF Budget Division, described developments the FY 2018 budget, the President's FY 2019 request, and recent NSF funding levels. The NSF appropriation for FY 2019 may be affected by raised budget caps, concern about international competition (especially in quantum technologies and artificial intelligence).

Discussion
Advisory Committee members noted challenges to NSF operations and strategy in an uncertain budget environment.

ADVISORY COMMITTEE REPORTS

Committee liaisons reported on recent activities:

Dr. Tilak Agerwala, liaison to the **Advisory Committee for Cyberinfrastructure** (ACCI), described progress on CI2030, the effort to identify cyberinfrastructure needs for future S&E research. The ACCI analyzed responses from the 2017 request for information (RFI). He described finding in areas such as people, resources, simulation, cybersecurity and education. Some needs, for example, in cyberinfrastructure resources, will require coordinated investment with external partners. The committee is on track to complete the CI2030 report over the summer.

Dr. Gilda Barabino, the brand-new liaison to the **Committee on Equal Opportunities in Science and Engineering** (CEOSE), reminded everyone that CEOSE is a Congressionally-mandated body that advises NSF on issues of broadening participation and diversity. CEOSE recommendations prompted NSF to launch the INCLUDES program.

Dr. Susan Butts described how the **Subcommittee for the Small Business Innovation Research/Small Business Technology Transfer Program** (SBIR/STTR) is changing to one in-person meeting per year instead of two and will hold additional conference calls. Four working groups — on assessment, broadening participation, deal flow, and entrepreneurial education — are all making good progress. Some working groups meet jointly for intersecting activities, such as increasing deal flow through broadening participation. Recent division activities will provide "on-ramps" into the SBIR/STTR program.

Dr. Pedro Alvarez, the liaison to the **Advisory Committee for Environmental Research and Education** (AC-ERE), introduced the committee's February report on sustainable urban systems. The report lays out a vision and an agenda for convergence research and education at different levels of complexity and

scale. The report encourages new data and methods, assessing sustainability outcomes, understanding levers for change, studies to advance a science of theories of change, predictive capabilities, and the science of knowledge coproduction.

A second initiative recognizes that a healthy environment goes hand in hand with a healthy economy, and we want to connect environmental research to national security and economic competitiveness. Soon a Request for Information will ask the community about environmental priorities that can contribute to the economy, security, or well-being; methods and education are needed; and what other drivers for environmental research and education need attention.

Discussion
ACCI: The committee asked about the engineering response to the RFI. Dr. Agerwala replied that about 18 of 136 responses were from engineers, and they were comprehensive. He noted that the engineering community may feel less prepared for cyberinfrastructure and thus didn't respond strongly. While the ACCI could have done more outreach, they are satisfied with the responses.

CEOSE: Committee members asked how many INCLUDES grants involve engineering, and Dr. Don Millard, acting division director for the Division of Engineering Education and Centers, said that about 8 of the 70 launch pilots involve engineering.

AC-ERE: The committee asked where resilience fits in sustainable urban systems, and Dr. Alvarez responded that it's always part of sustainability and thus the report and related papers. The group discussed the role for engineering in the mitigation of climate change by, for example, managing extreme events that affect urban areas, strengthening science education, rethinking building standards, or simply asking, "What if your city flooded?"

VISIONING FOR ENGINEERING

Dr. Tilbury introduced the Directorate's goals for visioning, which include: incorporating broad community input, considering all of engineering, identifying new research directions, and creating impactful reports. She provided examples of visioning activities and asked the committee to think about how to incorporate input, how to develop report topics, and how to balance the roles of academia, industry, and government.

CCC: VISIONING FOR COMPUTING RESEARCH

Dr. Erwin Gianchandani, deputy assistant director for the Directorate for Computer and Information Science and Engineering (CISE), provided his perspectives on the Computing Community Consortium (CCC). He described its role as both a research catalyst and enabler. For example, it encourages the alignment of computing research with national priorities and challenges, and it brings all types of departments and schools together into the CISE community. Structurally, it operates as "standing committee" of the Computing Research Association and is funded by NSF through a cooperative agreement for visioning activities. CCC encouraged community experts to prepare white papers for sharing with government agencies on big data, leading to the BIGDATA R&D Initiative. They contributed to the national roadmap for robotics and the National Robotics Initiative, and they engaged the computer science community on brain-related challenges for computing and the NSF Understanding the Brain investment. The CCC also began the Computing Innovation Fellows program following the Great Recession, when academic hiring had paused. NSF invested $30 million for 1- to 2-year postdoctoral

fellowship positions to retain new PhDs in research and teaching. In addition, the CCC conducts many workshops and symposia, as well as communications activities to bring the community together.

Discussion
The committee asked about the diversity of the postdocs, and Dr. Gianchandani said that the Computing Innovation Fellows were significantly more diverse than the historical computer science community, for example, women were about 40% of fellows compared to about 20% in field.

Committee members asked what portion of ideas become initiatives and what is the timescale involved, since computer science changes fast and industry does so much research. Dr. Gianchandani explained that they have examples of initiatives and programs with rapid growth and change but not quantitative information about that.

The committee discussed how computer science is part of many grand challenges that require working together with engineers and others to make progress for the economy and national security. Engineers have been present at many of these workshops, and it would be valuable for other disciplines too (for example, for health IT).

M-FORESIGHT: VISIONING FOR ADVANCED RESEARCH MANUFACTURING

Dr. Bruce Kramer, senior advisor in the Division of Civil, Mechanical and Manufacturing Innovation, introduced the Alliance for Manufacturing Foresight, or M-Foresight — a consortium of thought leaders from industry and academia focused on the future of U.S. manufacturing. It was created to provide objective opinions on opportunities and challenges in manufacturing, which it does through stakeholder engagement and community-building. M-Foresight was inspired by the CCC and grew out of the Advanced Manufacturing Partnership 1.0 Report. The consortium and its reports have become high-profile in the community and on Capitol Hill. NSF aims for it to become self-sustaining; M-Foresight is finishing up its strategic plan now.

DOE WORKSHOPS: VISIONING FOR BASIC ENERGY RESEARCH

Dr. Linda Blevins, deputy assistant director for Engineering, introduced the Department of Energy (DOE) Basic Energy Sciences (BES) workshop series for basic research needs. The BES advisory committee developed a research map and initiated workshops in specific areas of the map. The workshops engaged research communities to help provide solutions to future U.S. energy challenges through a rigorous process that resulted in concise, authoritative, science-heavy reports identifying basic science gaps. After 10 workshops over five years, the BES advisory committee produced a report on grand challenges. Outcomes from the report include community and stakeholder buy-in on research directions, new funding opportunities and research outcomes, and increased budgets for BES.

Discussion
The committee discussed the value of looking at fundamental questions, and how applied areas of DOE and industry may be involved. Dr. Blevins commented that it is important to both differentiate and integrate basic and applied research at times, and to ensure a broad range of perspectives.

ENGINEERING BREAK-OUT SESSIONS AND DISCUSSION ON VISIONING FOR ENGINEERING

The committee held small-group discussions and reported back on three questions.

Question 1: How should the topics for reports be developed?
One group suggested starting with engineering and focusing on societal needs and challenges that lend themselves to a contribution from engineering, rather than scientific approaches (such as robotics). Then the societal needs can be broken into pieces that allow others beyond engineering to imagine how their skills can be used in that space.

Another group suggested looking at the type of research NSF should do and relate it to grand challenge themes. Research should be foundational research, not just fundamental, and often may be convergence research.

The third group suggested leveraging the societal grand challenges as a theme and finding where engineering has capacity to address them. Engineering should be at the center of most entities. We also need to map workshops on engineering grand challenges back to the NSF Big Ideas. Other approaches are to find grand opportunities or tackle an issue or challenge at a level just below a grand challenge that are still impactful, such as flooding.

Question 2: What are the best ways to incorporate broad community input?
One group described the benefits of an ideas-lab approach and having face-to-face workshops. To make this approach really work, organizers must reach out to people who might not self-identify as experts and hold ideation sessions without applying filters to ideas during the session.

Another group suggested creating moonshots on wicked problems; these could have applications in many fields.

The third group noted that it is necessary to try to widen the community and engage people who are not part of discussions today, such as underrepresented minorities, economically disadvantaged people, and others. A broad group can be involved in both workshop development and participation.

Question 3: What is the role for industry vs. academia vs. government in such an endeavor?
The first group suggested that industry, academia, government and non-profits be part of the discussion and ideation to build a balanced innovation ecosystem.

Another group stressed the importance of building partnerships to bring together organizations with different roles and priorities.

The third group noted that while nonprofits perform a limited amount of research compared to government, they are still very effective in focused areas. Different partners (for example, foundations, industry, and national labs) will bring different perspectives and goals, and it is important to understand them and what capabilities they bring.

Discussion
Committee members supported a visioning activity for the Engineering Directorate and recognized that the engineering profession is being transformed in many fundamental ways. Whatever process is chosen must incorporate that transformation.

They suggested looking for challenges beyond those named by the National Academy of Engineering and building on student interest in working on research with clear relevance.

Engineering could think about which parts of which models might help, keeping in mind that the purpose is to help the community do important things well.

TOPICS FOR DISCUSSION WITH THE DIRECTOR

Advisory Committee members discussed how to measure the success of convergence and other cross-directorate collaborations; the role for engineering in additional opportunities for convergence research; managing the uncertainty of funding and research directions; the dramatic increase in engineering enrollment in the last decade, and a new downturn with fewer international students; and the evolution of NSF INCLUDES. They decided to share these topics with the NSF Director the next morning.

The meeting adjourned for the day at 5:10 pm.

Wednesday, April 18, 2018

The meeting resumed at 8:32 a.m.

Dr. Pines summarized the previous day and asked for further thoughts. Members were encouraged by the interest in visioning and the CCC, which transformed the computer science community. A similar transformation is possible and important for engineering and would help it speak with one voice.

ROUNDTABLE ON STRATEGIC RECOMMENDATIONS FOR ENGINEERING

Dr. Pines opened the discussion with by asking about the possibility of partnering with foundations in fundamental research. Committee members noted a related National Academies panel on the subject and encouraged partnerships with non-governmental organizations and industry in research as well as outreach. Foundations attract a lot of money and can be an example of best practices for visioning problems, determining best practices, and attracting talent from around the world. NSF would need to consider the goals and scope, as well as learn from foundations themselves about their varied interests.

The committee also discussed opportunities that may come by blending social sciences with engineering. The collective impact approach is just one approach. Remember that heterogenous groups perform better.

The U.S. can improve its impact by improving how we do research and innovation and how to educate students to become value creators. In U.S. high schools, engineering is not necessarily seen as a way to impact the world, while in Europe it is seen as a pathway to leadership in industry and government. We need messages about engineering that are inclusive and resonate with the broader population. Engineering grand challenges can help inspire students, and we need a mechanism for engineering to propose solutions or paths to solve them.

PERSPECTIVE FROM THE DIRECTOR'S OFFICE

Dawn introduced Dr. France Córdova, NSF director, and Dr. Joan Ferrini-Mundy, NSF chief operating officer. The committee introduced themselves.

Dr. France Córdova thanked the committee for their service and advice that informs the NSF vision and goals. She expressed appreciation for the contributions of Dr. Tilbury and noted the importance of teamwork to leading NSF.

Dr. Gregory Washington inquired how NSF manages its budgets amid uncertainty. Dr. Córdova explained that NSF keeps in mind that many of the budgets the agency prepares, whether higher or lower, are not actual, and that actual appropriations are flat. NSF focuses on what we can really get done while responding to what is asked of us. We focus on the NSF mission and its value. We are investing in a lot of new directions that form a strategic framework for the future.

Dr. Agerwala described earlier discussion about getting the right kinds of collaborations to happen. He asked whether the Big Ideas are driving the right kind of cross-directorate collaborations and how NSF is measuring that. Dr. Córdova replied that NSF does not yet know the answer to the first question, although we know some previous models did not work. With the Big Ideas we began a new model of stewardship with entire funding for a Big Idea in one directorate — for example, Engineering is the steward for the Future of Work at the Human-Technology Frontier — and participation from many directorates. Universities have interdisciplinary research institutes, but those are harder to do in government. This model will begin in FY 2019, and we think it will force us to really work together. One way to know if it works is to receive an abundance of high-quality proposals that lead to significant discoveries. Dr. Joan Ferrini-Mundy added that NSF needs operations to support this vision of stewardship, which is connected to the streamlining and lowering of bureaucratic hurdles as part of Renewing NSF.

Dr. Maxine Savitz expressed concern about uncertainties in U.S. immigration policies and the impacts on STEM students and the STEM workforce, and ultimately on STEM leadership. She asked what NSF is doing to address the concern at both levels. Dr. Córdova agreed it is a concern, and the National Science Board uses data from the National Center for Science Engineering Statistics to understand trends. NSF has been putting effort into NSF INCLUDES and other education programs to increase the domestic base of STEM workers in the long run. Right now, we are in a tenuous position and are asking for flexibility. Our message is to invest in the U.S. rather than limit other countries. NSF is working with other organizations to share what universities and the nation have gained. Dr. Ferrini-Mundy added that the NSF Graduate Research Fellowship Program each year gets 12,000 to 16,000 applications and awards 2,000 fellowships and another 2,000 honorable mentions. We have students in the pipeline and need to find ways to support those students.

Dr. Sarah Rajala noted the role and importance of convergence research in addressing NSF Big Ideas, and the role individual engineers play in those. She asked what NSF will do to encourage more convergence research to address new challenges and opportunities Dr. Córdova responded that the National Academies report about NSF Engineering Research Centers recommended convergence research. Centers may be able to adopt convergence research more readily. NSF has to organize internal processes to facilitate convergence research rather than use them as an excuse not to fund it, and we have some work to do within NSF to encourage funding across boundaries. NSF announced in early May a collaboration with the Air Force several areas of collaboration that may inspire engineering. NSF meets with DOE today and met with National Institutes of Health last week about collaborations. NSF is involved in many National Science and Technology Council committees and participates frequently on government panels. We're trying to put convergence into everything we do and bring awareness about it through public venues.

Dr. Barabino observed that engineering contributes a creative and design mindset to broadening participation, and NSF INCLUDES is important for broadening participation in engineering. As INCLUDES evolves, how we can maximize this two-way exchange? Dr. Córdova replied that INCLUDES and the model of collective action can accept contributions from all fields and parts of NSF. She is interested in getting engineering ideas on how INCLUDES Alliances are working. Dr. Ferrini-Mundy remarked that conceptual engineering contributions to INCLUDES (such as systems, scaling, networks of networks) have been essential. NSF is learning and is alert for any necessary mid-course corrections. We now have proposals for alliances and coordination hubs, which we hope will form basis for a national network. Many launch pilots in the first two cohorts are in engineering. Also, to accelerate the network, we held a summit in January with leads from center-scale activities to introduce them to INCLUDES and resources that can help them join. Dr. Córdova added that like the Engineering activities to help nascent technologies across the valley of death, NSF has prototypes to help INCLUDES collaborations scale and take on a life of their own.

Dr. Lutchen said that the way the NSF Big Ideas concepts inspire the broad community is similar to how grand challenges have inspired the engineering community and spurred enrollments. How can engineering expand this trend to interdisciplinary and convergence research and facilitate success in the Big Ideas? Dr. Córdova said that messaging about how engineering is connected to and critical to all big ideas — now and in the future — is essential. The NSF Idea Machine competition can include students down to age 14 and could be a homework assignment for engineering. There is a lot of potential.

Dr. Carlson asked what research agenda might accommodate an exponential change in students and technology transformation. Dr. Córdova asked the committee to imagine it, because it must be done together. We all have to envision that world that we want and work for it. What will we do with new students once we've got them? NSF embraces the vision of our stakeholders and helps provide resources.

Dr. Pines thanked Dr. Córdova and Dr. Ferrini-Mundy for their work at NSF and for the day's discussion.

Dr. Pines and **Dr. Tilbury** recognized departing committee members Dr. Reggie DesRoches and Dr. Susan Butts.

SPECIAL SESSION BEGINS

Members of the Advisory Committee for Polar Programs joined the meeting.

A VISION FOR NAVIGATING THE NEW ARCTIC

Dr. Tilbury explained that engineering can contribute all NSF Big Ideas. The purpose of this special session is to find engineering opportunities in Navigating the New Arctic, such as engineering for extreme environments.

Dr. Kelly Falkner, office director of the Office of Polar Programs, introduced the polar programs office and their hope to partner with will all areas of science and engineering supported by NSF.

Committee members and ENG leadership introduced themselves.

ARCTIC DESIGN GROUP. MEDIATING ENVIRONMENTS

Dr. Matthew Jull, of the University of Virginia, described his background as a geophysicist interested in how people interact with environment and the tension there. He became an architect and spent time in Iceland, where he saw volcanoes and natural events being treated as an inconvenience. An old design concept for an Arctic city shows it under a dome, negating and neutralizing its environment. The Arctic can be a frontier of innovation and of extremes, but one also can think of it as a context for a new way of building cities.

Permafrost is a dynamic material formed and patterned through millennia. How can we design cites in this context? How do we see their future? Look back at how people have lived there, with ingenious structures for nomadic living; there is a lot of intelligence to learn from for the future. But it is clear the Arctic is changing, and sea ice is melting. What this will do in terms of livelihood of people is uncertain, but it will lead to transformation. Coastal erosion is affecting communities along the shoreline now. Natural resource extraction, geopolitical changes, shipping opportunities — people tend to see the Arctic in a way that reflects their own interests. Forces on the Arctic are being debated by the Arctic Council and business interests.

Design is not about optimization of extraction or solving problems that are related to an economic future, but about how to culturally optimize and how to use materials and waste. To look forward, look back at what exists now and Arctic city growth. We often see a suburbanized community, like Barrow, Alaska, compared to industrialized cities in Russia, and there is much to learn from them. Comparing aerial views shows different design approaches. The Russian people developed a lot of technology (for example, concrete for subzero temperatures). We have inadequate knowledge on how to design buildings and infrastructure in melting permafrost. Other options are hyper-insulated spaces, spaces that are efficient and compact, or autonomous city enclaves that accommodate wind and snow.

With Leena Cho, Jull developed a map of critical areas and how their built environments are developing. They bring people together to think about possible futures, talking in Russia about improving post-Soviet cities, working in eastern Siberia with students to use design to reintegrate with the natural environment. He brings students to the Arctic for research in different climate zones. Design synthesizes many things: culture, engineering, botany, sociology, and others. He asks student to look at fundamentals of the environment and begin simulations about how the built environment interacts with natural conditions. The condition of buildings in rural Alaska is very challenging, without running water or sewage, and leads to health and environmental challenges that are exacerbated by a changing climate. They look at basic systems that define housing and design new structures based on how people use spaces. The students also look at the design of outdoor spaces that change seasonally. Other issues are schools, which typically are poorly designed, and barrier island communities that need to relocate because of coastal erosion. Another big problem is food security, which puts health in jeopardy across Alaska. People living in rural Alaska really need more resources as they confront climate change. Students learn to listen to people there.

NSF PIRE is funding an index of sustainability in Arctic cities. The team is developing a body of data and indices to help define best practices. NSF also funded a workshop in Charlottesville on science, art and community, where Alaska native youth will come and tell designers how they interact with environment. Jull believes in cross-disciplinary work, between architecture and engineering. Disciplinary expertise is important, but coproduction of knowledge is critical.

Discussion
Committee members asked about the use of traditional materials like sod, whalebone, driftwood, and others that do not need to be imported. Dr. Jull explained that logistics and availability of materials are critical. It is possible to use sod, but only a certain amount of bone and driftwood is available at any one time and place. Native people understand the environment and believe in technology, and they want things that are responsive to cultural and social needs and to cost. They must consider the logistics of available materials and changes in performance and production compared to imports. In Alaska, there is great growth in smart buildings and sensing technologies.

OPPORTUNITIES FOR ENGINEERING IN NAVIGATING THE NEW ARCTIC

Dr. Deborah Goodings, division director of the Division of Civil, Mechanical and Manufacturing Innovation, said that engineering can collaborate with other disciplines to help make a greater impact. The new Arctic region extends beyond the Arctic circle. With increased melting of sea ice, ships can traverse the Arctic passage without an ice breaker. This signals changes to population size, security, and the economy (in, for example, resource recovery, especially oil and natural gas).

The U.S. Arctic Executive Steering Committee has created a national strategy for Arctic region that focuses on: improving economic and living conditions; ocean safety, security, and stewardship; addressing climate change impacts; and international cooperation. Navigating the New Arctic aligns with this strategy. In FY 2017 NSF funded research coordination networks and workshop, and in FY 2018 NSF called for more proposals in research and education.

Some existing and potential ENG contributions for Navigating the New Arctic are relate to natural processes such as coastal erosion; economic development such as energy distribution; and infrastructure for people, industry, and security.

BREAK-OUT SESSIONS AND DISCUSSION ON NAVIGATING THE NEW ARCTIC

Dr. Goodings introduced the discussion questions. The committees held joint small-group discussions and reported back on four questions about Navigating the New Arctic (NNA).

Question 1: What are the NNA fundamental research challenges where engineers make a significant contribution?
We need to define the NNA challenges in the context of engineering. Engineers have extensive experience working in extreme environments that can be applicable in the Arctic environment. Fundamental challenges include: infrastructure and robotics in extreme environments; systems engineering and supply chain management to Alaska; community planning and smart buildings that incorporate community feedback and build trust. One grand challenge is the advancement of robotics in extreme environments. These activities require fundamental, convergent work in mechanics, sensors, communication, and artificial intelligence. NSF should engage researchers across the nation in NNA challenges through a series of workshops that identify paradigm shifting challenges and incorporate representatives from arctic communities. NSF can use existing environment-related programs as examples — Solar Decathlon and Singapore Smart Cities Initiatives — as examples to inform new activities. NSF should focus on engaging local communities, who need to buy in to new initiatives. The engineering community must build equity with arctic communities.

Question 2: What are the NNA fundamental research challenges where NSF ENG could collaborate with other Directorates?
Many, urgent research challenges have the potential for Engineering collaboration, and the unfortunate situation in the Arctic can serve as a testbed to make predictions. Indigenous communities need to be involved from the beginning.

We need a huge amount of sensing capability that doesn't exist today for continuous monitoring of Arctic natural processes and infrastructure; computational modeling plays a key role, but physical data is needed to validate the models to know they are accurate.

There is a gap between the research on building better houses and the daily lives of people in the Arctic. Engineering research requires deep collaboration with local communities, a systems approach that considers social and economic issues, and the creation of adaptive tools that can work in many situations.

Question 3: What NNA research challenges (with strong ENG involvement) should NSF explore through partnerships?
The group suggested many research challenges where partnerships would be helpful: internet connectivity and bandwidth, power assistance, infrastructure, smart and connected communities, risk mitigation, chemical engineering, vessel design, data analytics, land transportation, and sensing. Addressing these challenges could involve a variety of possible partners. Government agencies could include: NASA, Department of Defense, U.S. Coast Guard, Department of Energy, NOAA, Environmental Protection Agency, the State of Alaska, and indigenous local communities. Industry partners could include: the aerospace and aeronautics industry, the oil industry, the insurance industry, big data companies, and research consortia. Arctic nations and Artic Coalition partners, as well as the United Nations and NATO, would have an interest in research related to shipping, transportation, risk mitigation, internet connectivity, and sustainability.

Question 4: What are the ENG-essential contributions to community wellbeing in the Arctic?
Local residents should define the terms of their well-being and quality of life. Researchers need a mindset of working with the community. Engineering can contribute supply chains for physical resources, information, and healthcare. Many traditional education venues in Alaska for broadening participation do not reach people in remote communities. Engineering can engage non-traditional education venues and pre-college students. The Directorate can look at Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) and Engineering Research Centers for opportunities. Alaska itself, as a living lab, should attract a lot of researchers. Engineering can partner with the Directorate for Social and Behavioral Sciences (SBE) and the Directorate for Education and Human Resources (EHR) to start collaborations.

SPECIAL SESSION ENDS

Dr. Tilbury thanked members of the Advisory Committee for Polar Programs, and they left the meeting.

CLOSING REMARKS AND WRAP-UP

Dr. Pines and **Dr. Tilbury** thanked the committee members and the NSF team.

The meeting adjourned at 12:35 p.m.