Directorate for Engineering Advisory Committee Meeting

National Science Foundation
Arlington, Virginia
April 27-28, 2016
Room 1235

ENG AdCom Members Present:
Dr. Louis Martin-Vega (Chair)
Dr. Pedro Alvarez
Dr. Gilda Barabino
Dr. Karen Butler-Purry
Dr. Susan Butts
Dr. Andres Clarens
Dr. Debasish Dutta
Dr. S. Shankar Sastry (virtual)

ENG AdCom Members Absent:
Dr. Curtis Carlson
Dr. Robert Chau
Dr. Reginald DesRoches
Dr. Henry Foley

ENG Senior Staff Present:
Dr. Pramod Khargonekar (Assistant Director)
Dr. Samir El-Ghazaly
Dr. Deborah Goodings
Dr. Barry Johnson
Dr. JoAnn Lighty
Dr. Sohi Rastegar
Dr. Mihail Roco
Dr. Mario Rotea
Dr. Grace Wang

Wednesday, April 27, 2016

The meeting convened at 12:10 p.m.

CALL TO ORDER

Dr. Louis Martin-Vega, chair of NSF Directorate for Engineering (ENG) Advisory Committee (AdCom), welcomed everyone to the meeting. AdCom members and ENG senior staff introduced themselves.

DIRECTORATE FOR ENGINEERING REPORT

Dr. Pramod Khargonekar, Assistant Director for Engineering, gave a warm welcome to new committee members. He introduced new ENG staff and described open positions. He described operational priorities for the directorate, some based on feedback from the Federal Employee Viewpoint Survey, and new processes to streamline the Directorate's work.

He then described research and education priorities for ENG in the fiscal year (FY) 2016 budget and FY 2017 request, which support NSF-wide investments and national initiatives. NSF investments where the Directorate plays a major role include: Innovations at the Nexus of Food, Energy and Water Systems (INFEWS); Risk and Resilience, particularly Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP); Understanding the Brain (UtB); and Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science (NSF INCLUDES). ENG continues to invest in advanced manufacturing; clean energy; Enhancing Access to the Radio Spectrum (EARS); the National Strategic Computing Initiative (NSCI); engineering education and

workforce development; Innovation Corps; and other areas. He also underlined the importance of funding in core programs that cover basic fields of engineering research.

Dr. Khargonekar concluded with themes, issues, and questions that the Directorate is grappling with for the future, including: NSF broader impacts, engagement in INCLUDES, and future strategies for advanced manufacturing, smart systems, and data-science enabled engineering research.

Discussion
AdCom members expressed interest in the ENG workshops on broader impact. They inquired about the status of the National Academies study on the future on multidisciplinary, center-based engineering research, and requested an update at their next meeting.

GERMINATION OF RESEARCH IDEAS FOR LARGE OPPORTUNIES AND CRITICAL SOCIETAL NEEDS OVERVIEW

Dr. Sohi Rastegar presented the GERMINATION program, which begins with a vision of NSF driving ground-breaking, high-impact, fundamental research in engineering in a time of national challenges and opportunities. The program explores the possibility of designing learning frameworks, platforms and/or nurturing experiential environments that maximize the probability of researchers formulating high impact research questions. GERMINATION considers the convergence of knowledge, tools, and ways of thinking from multiple science and engineering disciplines at the point of research question formulation to be a critical factor in laying the foundation for high impact discoveries.

Dr. Rastegar introduced the five GERMINATION projects funded in FY 2016 and asked: how can effective learning frameworks, platforms and/or nurturing experimental environments be designed in which targeted participants are stimulated to germinate transformative research ideas and questions to open large opportunities for surprising new discoveries and/or breakthrough solutions to pressing societal problems or grand challenges?

Discussion
AdCom members discussed the likelihood of GERMINATION continuing or expanding in the future, and Dr. Khargonekar explained that it depended upon this exploratory stage. In the future, GERMINATION may target activities for graduate students and may serve as a means to broaden participation in engineering. Members noted that ENG may consider expanding to other directorates and creative spaces beyond academia that create value.

PANEL DISCUSSION ON NSF INCLUDES

The panel involved Dr. Joan Ferrini-Mundy, Assistant Director for Education and Human Resources (EHR); Dr. Suzanne Iacono, Head, Office of Integrative Activities; Dr. Sylvia James, Division Director, EHR Division of Human Resource Development; Dr. Khargonekar; and Dr. Mario Rotea, Division Director, ENG Division of Engineering Education and Centers.

Dr. Rotea and Dr. James introduced NSF INCLUDES, which was created in response to the Committee on Equal Opportunities in Science and Engineering (CEOSE) recommendation to develop new research and use the social sciences to scale up participation of underrepresented groups in science and engineering. The program has three essential components: design and development launch pilots, alliances, and backbone organizations. Using a systems approach to set the conditions for collective impact, NSF

INCLUDES will launch its pilot programs in FY 2016, fund up to five alliances in 2017, and then expand alliances and support a national backbone organization in 2018 to 2021. A distinguishing aspect of NSF INCLUDES will be its emphasis on scaling, with pilot awards being two years of up to $300,000 in funding.

Dr. Ferrini-Mundy, Dr. Iacono and Dr. James noted the deep engagement in INCLUDES across NSF, and emphasized NSF will be learning as projects are implemented about which elements are most important. Dr. Rotea added that risk is driven by the size of the challenge and not a lack of support or understanding.

Dr. Khargonekar remarked that a common agenda is critical for INCLUDES to succeed, because in the past many organizations have worked on these same issues without coming into alignment. He also mentioned that a national network would provide an on-ramp for people joining alliances at different times after the initial launch, supporting innovative ideas that are perhaps not yet fully formed.

Discussion
AdCom members asked how common agendas and goals will develop. Panelists noted that flexible backbone organizations will provide "neural intelligence" to mutually reinforcing activities. NSF is taking a portfolio approach to the alliances across the nation while being heterogeneous within themselves and their specific backbones.

The collective impact approach means that proposals begin with a specific challenge and prospective partners; shared goals are determined during the process and depend in part on the partners. Strategies of typical proposals won't apply, which is why NSF is starting with pilot activities. The difference is the focus on scaling, which may not mean replication as new partners will be involved. Scale may extend across the country but also throughout a campus, so all students have the opportunity to thrive.

Dr. Dutta shared that Purdue University is focused on three areas: recruitment, retention and climate. Climate is where education needs to make the most progress.

ENABLING A POST-MOORE'S LAW FUTURE: ENERGY EFFICIENT COMPUTING

Dr. Samir El-Ghazaly, Division Director for the ENG Division of Electrical, Communications and Cyber Systems (ECCS), introduced the panel and gave an overview of the development of silicon-based electronics under Moore's law. Despite investment and advances, we haven't cracked the problem yet.

Dr. Khargonekar stated that, in the next 10 years, a disruptive change or inflection point will occur. ENG must catalyze and lead that change. In a new solicitation on energy efficient computing, the research interests of ENG align with those of academia and the private sector.

Dr. Tom Theis, Executive Director of Nano Initiative, Columbia University, explained that advances in clock frequency, power and other areas have flattened out in in the last 10-15 years. Limitations come from heat and economic limits. While innovation continues, these advances won't sustain performance improvements. We must explore new devices and architectures.

Dr. Dimitris Pavlidis, ECCS program director, described the NSF investment in Energy Efficient Computing: from Devices to Architectures (E2CDA) that seeks an integrated approach from materials to

devices to 3D architecture to get close to the functionality of the brain, which uses less power and is fault-tolerant.

Dr. Sankar Basu, program Director, Directorate for Computer and Information Science and Engineering (CISE), Division of Computing and Communication Foundations (CCF), explained that we are at the end of the traditional scaling of computing performance and design hierarchy is extremely complicated. Last June OSTP issued a nanotechnology-inspired grand challenge for future computing that combines big data, artificial intelligence, and brain science. Computing stack layers were operated and designed independently in the past, but that must change.

Dr. Celia Merzbacher, Vice President for Innovative Partnerships, Semiconductor Research Corporation, described SRC's partnership activities with NSF since the 1980s. Joint workshops identify new areas of interest, and pool money driven towards industry "hard problems." SRC helps remove friction between academia and industry and enhance student education through mentorship and special events.

Discussion
AdCom members discussed the long-term nature of the required investment because the problems are so massive. Carbon nanotubes will help for a while, but then we need architectural innovation. Nanoelectronics may also hold promise, and NSF is leading the way.

TOPICS FOR DISCUSSION WITH NSF LEADERSHIP

AdCom members discussed their ideas and concerns about NSF INCLUDES, including the arts in engineering and STEM education, and applied versus fundamental engineering research, and they decided to share these topics with the NSF Director the next morning.

The meeting adjourned for the day at 5:38 p.m.

Thursday, April 28, 2016

The meeting reconvened at 8:35 a.m.

Dr. Martin-Vega welcomed NSF Director France Córdova, and Advisory Committee members and ENG senior management introduced themselves.

PERSPECTIVE FROM THE OFFICE OF THE DIRECTOR

Dr. Córdova expressed her appreciation of Advisory Committee feedback and ideas, and her pride in the positive ENG budget trajectory. She thanked Dr. Khargonekar for his leadership, his support for broadening participation, and his outreach on the importance of basic science for the country.

Discussion
Dr. Barabino thanked all those who developed NSF INCLUDES to address the complex and intractable problems around inclusion and broadening participation. How do we engage and equip the engineering community to participate effectively? Dr. Córdova responded that engineering can make very important contributions by offering a design sense of how to approach this problem and by analyzing INCLUDES pilots for approaches we can scale.

She continued to say to the engineering profession is attractive to many people looking for education that leads to jobs. However inclusion is an issue even for attractive fields, and we can get complacent when the seats are full. Counting on the rest of the world to fill these seats is not a sustainable model, and it is not fair to the youth in our country. It takes long-term work to capture a young engineer, and we must lay the groundwork.

Dr. Dutta asked how NSF can incentivize a positive climate for women, students of color, and LGBTQ students. Dr. Córdova said that we learned from the NSF ADVANCE program that faculty and administration buy-in and institutional commitment are very important. We need to engage people to get them to trust and aspire to higher levels of institutional leadership. NSF looks for bold ideas that we can attempt.

Dr. Butler-Purry remarked that many broadening participation programs have been effective in their environments but haven't scaled much past boutique-scale. We are struggling to apply successful cases as models. Dr. Córdova replied that NSF INCLUDES looks for partnerships using models we have learned from and expanding the model to a bigger network and more people.

Dr. Butler-Purry then asked how NSF will hold principal investigators responsible for the students they select and mentor. Dr. Córdova suggested that improvements to mentoring and advising begin with conversations between universities and their students and fellows, and learning about what they value (which may depend on the field). The National Science Board is looking at the quality of graduate education. Where NSF can support these efforts through changing our solicitations, we will.

The conversation shifted to the types of engineering research funded by NSF. Dr. Alvarez asked how Engineering can balance NSF's mission in basic science with immediate and specific needs of industry, such as in the area of creating post-Moore's law technologies. Dr. Córdova commended ENG for blurring the line between basic and applied research, through programs such as Innovation Corps, Industry/University Cooperative Research Centers, and Small Business in Innovation Research.

Dr. Clarens asked about the relationship between engineering and design, and incorporating art into STEM education. Dr. Córdova replied that it's important for engineering to foster a relationship with design, especially where sciences converge for problem formulation. The Directorate for Education and Human Resources has support projects looking at art and design.

Dr. Córdova thanked the AdCom members for the discussion and input, and they voiced their appreciation.

SOCIETAL-SCALE CYBER-PHYSICAL SYSTEMS: BIG DATA MEETS PRIVACY AND INCENTIVE DESIGN

Dr. Sastry explained how action webs lead to societal-scale cyber-physical systems (CPS). Action webs are involve sensory swarms that observe and infer for planning and modifying action. They may be used to lower costs and improve reliability, but vulnerabilities and privacy/security issues emerge. Societal-scale CPS are complex collections of sensors, controllers, compute nodes, and actuators that work together to improve our daily lives, and they offer great economic promise in areas such as smart health, the electrical grid and transportation systems.

To function optimally, societal-scale CPS may include incentives to shift consumer demand. Incentives rely on game theoretic models, which must be designed to avoid vulnerabilities from adversarial agents. Data analytics are helping monetize CPS big data, and new markets for data are emerging. Data aggregators, who provide data to users, are a new group involved and promise of operational efficiency.

Disaggregated data has useful information and also personal information, for example, smart meters show which devices are being used, and usage patterns can reveal a household's economic profile. So what began as a way to improve efficiency has quickly led to questions about economics and security/privacy, and design needs to pay attention to these questions. Smart infrastructure empowered by the internet of things has at its core an ecosystem consisting of a shared economy, which may operate outside of existing regulations and policies. In the future, research must address new types of vulnerabilities, attacks and defenses to achieve desired privacy, security and reliability.

COMPUTING EMBEDDED AROUND, ON, AND WITHIN US: THE HUMAN-TECHNOLOGY FRONTIER AND ITS INTERDISCIPINARY IMPERATIVE

Dr. James Kurose, NSF assistant director for Computer and Information Science and Engineering (CISE), stated that ENG and CISE will continue their strong collaboration to address two important, urgent challenges: the human-technology frontier and harnessing the data revolution.

The human-technology frontier begins with the human. Computing will be different and personal in the future because it will be embedded everywhere: clothing, materials, devices, etc. This ecosystem must be designed to benefit people in their everyday lives – many science and engineering challenges must be overcome to meet this goal, such as energy efficiency, machine learning, and security.

Harnessing data will be then next science and technology revolution, affecting all areas of science and engineering practice. Fundamental research and workforce development will enable data-driven discovery and decision-making though visualization, modeling and analysis of complex data.

NSF uniquely positioned to lead these challenges through research, research infrastructure and education.

DISCUSSION ON ENGINEERING RESEARCH IN A WORLD OF BIG DATA

The group suggested that industry is ahead of academia in these area. Engineering has taken advantage of data in research related to neuroscience, nanoscience and engineering, and hazards, but these are exceptions to the rule. These challenges exemplify and promote convergence and inspire new research questions.

In terms of engineering education, universities are struggling to identify which tools to train students to use. Many areas of research need access to real data to design realistic approaches to problems, but privacy and security must be respected. The professoriate needs to adapt and bring themselves up to speed.

Dr. Kurose referenced the changes in biological sciences undergraduate curriculum with big data in mind, and the National Academies study on applied computer science and computational thinking for non-majors who wish to be data-enabled and fluent.

CYBERMANUFACTURING SYSTEMS

Dr. Bruce Kramer shared a briefing prepared for the House Manufacturing Caucus and House Maker Caucus on NSF activities pertaining to cybermanufacturing. He began by describing NSF's concept of manufacturing as a service and the tools needed to create sustainable web-based manufacturing services, which universities can help develop through basic research. He introduced cybermanufacturing research projects to facilitate access to manufacturing by people without design or engineering experience, with the help of user apps, decision tools, calibration, cybersecurity measures, visualization interfaces, machine learning and other technologies. Such research is being funded by the NSF Directorates for Engineering and for Computer and Information Science and Engineering, who are 100 percent partners in this effort.

REPORTING FROM BREAK-OUT SESSIONS AND ROUNDTABLE ON ENG STRATEGIC ACTIVITIES

Dr. Barabino reported for the first group: The sky is the limit with respect to what engineering could do with data science, for example, using data in a predictive manner, or for models where experiments can't be done (such as a nuclear reactor or natural disaster). Data interoperability, privacy and security and heterogeneity are potential issues that may require bringing in other expertise and computational tools. Big data may enhance research moving toward convergence. Experimental and theoretical communities may come together, and researchers in industry could become involved too.

Others noted the recent NSF workshop on convergence, and that big data could be a platform that facilitates convergence through the exchange of insights. Also, reproducibility and open data have implications for how and when data are recorded and shared.

Dr. Butler-Purry reported for the second group: New research frontiers may include urban systems and sustainability, connecting different systems, food-energy-water systems. Big data could also affect engineering education, especially through education delivery and perhaps personalized instruction to improve student success. Regarding shared data, we need to know what the community wants, what data sets need to be shared, and how to prioritize where to put resources. We'll need context for data and probably middleware, which wouldn't be provided by individual investigated. Workshops would enable the community to come together around these questions. In the future, researchers need to see value in having the data. Education may need to change, in terms of fundamental engineering and research mentoring. Also, if this is a new norm, how does that impact appreciation of the types of work done before (experimental and mathematical work)?

RECOGNITION OF DEPARTING ADVISORY COMMITTEE MEMBERS

Dr. Khargonekar expressed deep gratitude to two members of the Committee whose terms ended at this meeting: Dr. Karen Butler-Purry and Dr. Andres Clarens.

CLOSING REMARKS AND WRAP-UP

Dr. Khargonekar reminded the Committee of their next meeting on October 19-20, 2016. Dr. Martin-Vega and Dr. Khargonekar offered their thanks to the committee members and NSF staff.

The meeting adjourned at 12:13 p.m.