ENGINEERING RESEARCH FRAMEWORK VISIONING SUMMIT

WORKSHOP SUMMARY

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Engineering Research Framework Visoning Summit - Workshop Summary

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JULY 16–18, 2019, ALEXANDRIA, VA

ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Washington, D.C.
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Deborah Crawford, Vice President for Research, George Mason University, and Lance Davis, former Vice President for Research and Development at Allied Signal, Inc., co-chaired the Summit Steering Committee. The Summit participants, a list of which can be found in Appendix III, provided the substance on which this summary is developed. Their contributions over the two days provided the bulk of the content of this publication.

The Visioning Summit project was funded by the National Science Foundation (EEC-1748840). The conceptual idea, planning, and structure of the Summit was by led by an Engineering Directorate Senior Staff Working Group chaired by Sohi Rastegar. Other members of the Working Group included: Filbert Bartoli, Linda Blevins, Richard Dickinson, Brian Gray, Louise R. Howe, Bruce Kramer, Don Millard, Graciela Narcho, T.J. (Lakis) Mountziaris, Kon-Well Wang, and NSF's Assistant Director for Engineering, Dawn Tilbury. Additional feedback and input was provided by the Engineering Directorate's Advisory Committee.

The following ASEE staffers made contributions on this project: Norman Fortenberry, Executive Director of ASEE, was the lead point of contact with NSF program officers in implementing the Summit goals, agenda, and activities. He was supported in the implementation and delivery of the Summit by Rocio Chavela, Director, Education and Career Development Department, Ray Phillips, Program Assistant, and Ashok Agrawal, Managing Director, Professional Services Sector. Mark Matthews, Editorial Director, wrote the Summary document. Nicola Nittoli, Creative Director, and Francis Igot, Sr. Graphic Designer, provided the layout and design of the Summit agenda and the Summary report, and Darcelle Larkin, Digital Content Producer, developed the Summit promotional videos.

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EXECUTIVE SUMMARY

At a 2-day workshop, leaders drawn from engineering societies, industrial research organizations, and engineering faculty at a variety of institutions joined government representatives to explore how the diverse engineering constituencies could identify and unite behind research priorities. Participants sought to find models whereby the community could continually build a consensus around new research priorities and recommend them to the National Science Foundation (NSF), other funders and policymakers, and the nation. Funded by NSF and hosted by the American Society for Engineering Education, the Engineering Research Framework Visioning Summit grew out of NSF's wish for a process in which a united engineering community would help chart bold and high-impact fundamental research directions.

Attendees discussed whether some or all of the anticipated needs identified by NSF could be met by one or more of a series of models presented: the Grand Challenges for Engineering in the 21st Century; the Computing Community Consortium (CCC); MForesight, a university-led manufacturing-focused think tank; a rigorous method used by the Department of Energy Office of Science to develop approaches to new research topics; and approaches to research and development at three aerospace companies. While many attendees favored CCC's model, it was not found to be a perfect fit for two reasons: first, it was seen as addressing a single field—computer science—whereas engineering covers many disciplines, and second, it was seen as having insufficient industrial representation within its leadership structure. Nonetheless, the idea of an independent organization of some type was considered attractive.

Exploring ways of ensuring that the proposed organization reflects "a diversity of perspectives," attendees suggested the organization cast a wide net, bringing in voices from, among other groups, non-engineering disciplines, community colleges, trade associations, and entrepreneurs. There was also a desire to ensure that in its deliberations, populations and communities under-participating in the research enterprise be appropriately represented. Likewise, a question of how to validate the proposed organization's approach generated a lengthy list of organizations and groups to consult, from professional societies to Nobel laureates.

Asked to recommend a path forward, several breakout groups suggested that NSF name a task force or panel that would come up with a vision statement, seek buy-in from the engineering community, and map the organization's work. Others thought the Engineering Directorate's Advisory Committee could fulfill that role. Some participants suggested that a request for proposals to develop or stand up an organization could be released. Alternatively, pitches might be made in "Shark Tank" fashion to a committee or council, or collected via crowd-sourcing.

INTRODUCTION

The Engineering Research Framework Visioning Summit, held July 16-18, 2019, in Alexandria, VA., brought together 44 attendees to deliberate on how to leverage a united engineering community to identify future engineering research directions.

The decision to hold a summit emerged from a working group representing the five divisions within NSF's engineering directorate and chaired by Sohi Rastegar, Head of NSF's Office of Emerging Frontiers and Multidisciplinary Activities. The American Society for Engineering Education (ASEE) was chosen to organize and plan the workshop under co-chairs Deborah Crawford, vice president for research at George Mason University and former president of the International Computer Science Institute, and Lance Davis, senior adviser and former executive officer at the National Academy of Engineering (NAE), who previously served in the Pentagon as deputy director for research and engineering and at Allied Signal as vice president for engineering.

The invitation letter from NSF Assistant Director for Engineering Dawn Tilbury stated that the U.S. engineering community would benefit from a mechanism for identifying and addressing research challenges and opportunities emerging at the interfaces of engineering disciplines and between engineering and other disciplines. Moreover, there would be particular value in having the community identify bold and transformative areas for engineering research.

Attendees were leaders drawn from engineering professional societies, large and small industrial research organizations, and public and private engineering colleges. Presentations included a keynote by C.D. (Dan) Mote Jr., immediate past president of the National Academy of Engineering (NAE), on the Grand Challenges for Engineering in the 21st Century and formation of the Grand Challenge Scholars Program; three models for development of a community-based research agenda; and three examples of research and development in the aerospace industry: a mid-size firm, Ball Aerospace, a specialty engine manufacturing facility (Rolls Royce Indianapolis); and the Lockheed Martin advanced research arm, "Skunkworks." A series of four facilitated breakout sessions responded to these questions:

- Informed/inspired by the models presented, what community-driven research models might work best for the broad engineering community? Based on what design principles?
- How do we ensure the incorporation of a diversity of perspectives, including but not limited to technical, organizational and societal dimensions?
- How best do we validate model(s) we've identified with the engineering community at large?
- How best do we pursue implementation of the model(s)?

The detailed Summit agenda is included in Appendix I.

At an opening reception, Dr. Tilbury outlined what her directorate hoped would come out of the Summit. (See Appendix II). "We want the visioning activity this week to lay out a plan or a path to bring the engineering community together to develop these future research directions that will place our nation in a leading position to achieve and realize a better future for us all." NSF's own vision for this effort calls for the engineering community to speak "with a unified voice on bold and high impact fundamental research directions that will drive rapid and efficient response to emerging opportunities and areas of national need." She said the new mechanism or structure discussed at the Summit would help NSF "do better" in shaping and driving research for the betterment of society and the planet. It would enable "the collective identification and definition of promising emerging engineering research opportunities and directions."

While potentially funded by NSF, the new formal or informal organization would be "driven by an independent communitybased group." It would strengthen connectivity and sharing of best practices among stakeholders, including academe, industry, societies, and other groups within engineering. "We want to achieve something here that is ambitious and maybe even a little audacious," Tilbury said, urging attendees to "think big." The aim would be to have the new organization up and running in about a year, which would roughly coincide with the start of the 2021 fiscal year. Linda Blevins, deputy assistant director for Engineering at NSF, told attendees the next morning that the Foundation would be "taking advantage of two things from the group you create: their research expertise, and their unity and harmony. Unified research visioning gives us very powerful tools to use as policy-makers. . .The possibilities of a community of experts working together, setting its own agenda and speaking with one voice, are truly endless."

This workshop summary strives to summarize, sequentially, presentations at the plenary sessions and each of the breakout group discussions. For the plenary sessions, it draws on transcripts from audio recordings and speaker slides. For the breakout discussions, it synthesizes detailed notes taken in each group's room.

MODELS FOR CONTEXT AND CONSIDERATION

A series of speakers sought to stimulate thinking around a vision, goals, and an appropriate organizational model for the new community-based engineering organization.

NATIONAL ACADEMY OF ENGINEERING GRAND CHALLENGES FOR THE 21ST CENTURY

In the opening keynote, C. D. (Dan) Mote Jr. told the story behind the National Academy of Engineering's Grand Challenges for Engineering in the 21st Century and the subsequent Grand Challenge Scholars program. In its global application, the vision statement accompanying the Challenges is the first of its kind, according to Mote, who stepped down in June 2019 after six years as NAE president. The Scholars program has grown to involve close to 100 universities, connections in 24 countries, and a number of graduates with Challenge-inspired competencies. Together, the Challenges and Scholars program serve as models for developing a vision statement, setting goals to achieve the vision, and building an organization to create the necessary talent pool.

Following the 2002 publication of the Greatest Engineering Achievements of the 20th Century, an NAE committee led by William Perry, former secretary of defense, grappled with how to present what the 21st century might bring. Recognizing that no one could predict a century's breakthroughs, they settled instead on a broad vision statement accompanied by a set of goals. The vision: "Continuation of life on the planet, making our world more sustainable, secure, healthy and joyful." As far as Mote could tell, this is the first vision for the planet in history. "No one, in any field, has created a planetary vision before." It doesn't pick out particular things to do. The 14 Grand Challenges are goals that must be achieved so the vision can be realized. They're not arbitrary, nor are they a random set of good ideas for engineering.

Finding the solution space required to deliver each goal "is where we start to see the rubber hit the proverbial road." That space was filled by today's generation of engineering students, a cohort that wants to work on global problems and create solutions with a transformational impact. "They want to get things done." The impetus for engaging students came from Tom Katsouleas, then-dean of engineering at Duke University, Olin College President Richard K. Miller, and University of Southern California Engineering Dean Yannis Yortsos. In 2009, the three seized upon the Grand Challenges as a source of inspiration for engineering students.

They created the Grand Challenge Scholars program—in Mote's view "probably the greatest transformation in engineering education in my lifetime." What seemed like an intractable problem—devising a program that different universities in the United States and overseas would follow—turned out not to be all that difficult. "They didn't talk about the program detail at all; they just decided to talk about the outcomes of the program that the students would realize." Every university that signed up would do so on the basis of agreeing to five competencies that each Grand Challenge Scholar would attain: mentored research/creative experience on a Grand Challenge-like topic; an understanding of the multidisciplinarity of engineering systems solutions developed through personal engagement; an understanding, preferably developed though experience, of the necessity of a viable business model for solution implementation; an understanding of different cultures, preferably through multicultural experiences, to ensure cultural acceptance of proposed engineering solutions; and an understanding that the engineering solutions should primarily serve people and society, reflecting social consciousness.

The program would leave it up to each university to determine how students would achieve these competencies. Mote compared the organization that emerged to the Starfish model in The Starfish and the Spider: *The Unstoppable Power of Leaderless Organizations* by Ori Brafman and Rod A. Beckstrom. Spiders are hierarchical structures, typified by universities, government labs, and NSF. "Starfish are organizations that have no central organizational structure to them at all," like Alcoholics Anonymous. Each is an independent unit. "So, these are very flexible organizations."

The universities that have adopted the Grand Challenge Scholars program remain independent of each other, and independent of the Academy, "except that they agree to the same general construct of these five competencies for the students." The resulting organization has been achieved without significant national or international funding. And it addresses key questions: "One is: what is engineering? Especially since we've never talked about people and society, it's very difficult to explain to the public. Secondly, how does engineering actually serve people and society? We've not done a very good job on that, and that's what the Grand Challenge, and the Grand Challenge Scholars Program, actually do."

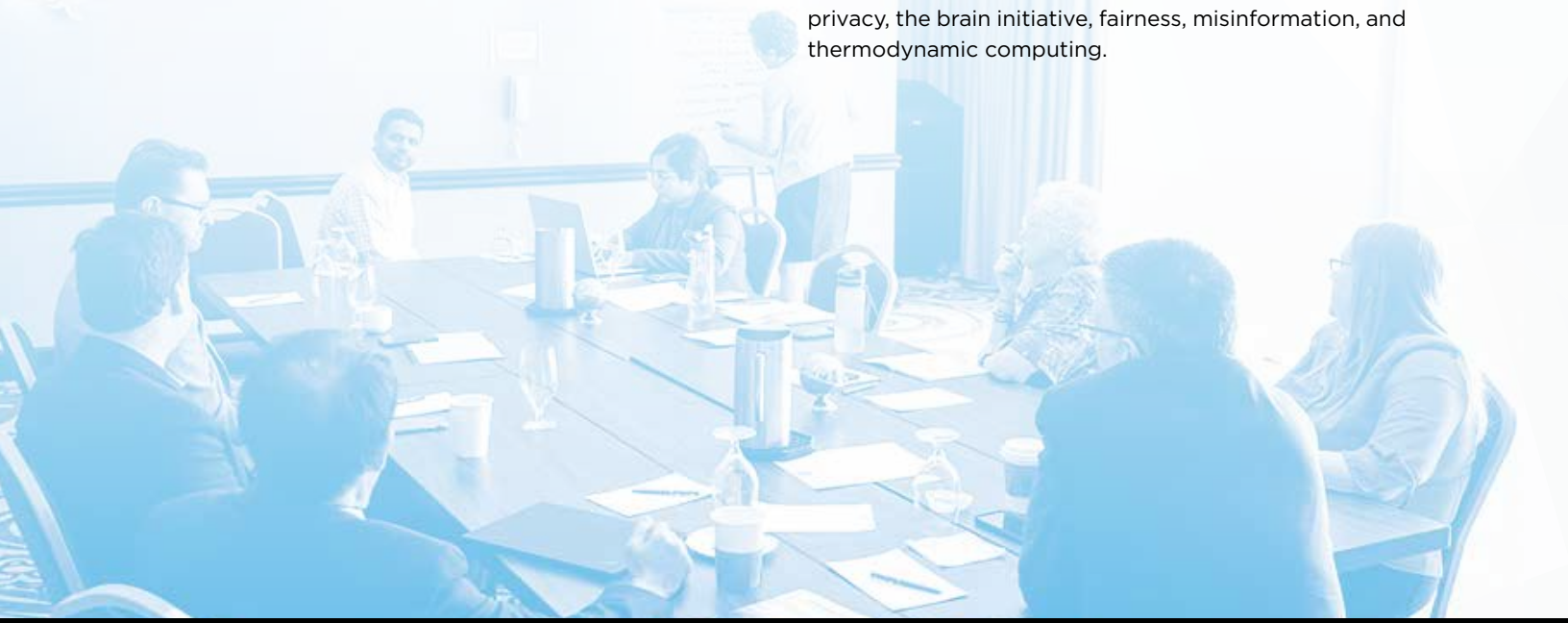
Returning to the NAE's 15-word vision statement, Mote urged participants to think about "how the ideas in that vision statement might map over to how you might structure the ideas for what you want to propose to NSF."

THE COMPUTING COMMUNITY CONSORTIUM

Ann Schwartz Drobnis is director of the Computer Community Consortium, an NSF-funded standing committee of the Computing Research Association (CRA). The CCC serves as a "catalyst and enabler" of revolutionary, audacious, high-impact research aligned with national priorities and challenges. It works to bring the computing community together, inculcate leadership values, inform and influence early-career researchers, and guide research funding.

Specific activities include managing seven task forces, running workshops (an average of 8 per year), a biannual symposium, early-career training, and conference blue-sky tracks. It issues whitepapers (36), and reports (20 so far). Its website has a Great Innovative Ideas feature that spotlights individual researchers. CCC also tweets, blogs, and has a biweekly podcast. Ideas for activities emerge from various sources, including contacts with policymakers, conferences, and responses to open calls to the community.

Its main focus is on "visioning activities"—meetings in which individuals or groups of four or five people talk about a topic, followed by small-group breakout sessions. Speakers are not allowed to talk about their own research. Topics in the past year and a half have included AI, post-quantum cryptography, health, privacy, the brain initiative, fairness, misinformation, and thermodynamic computing.



The CCC operates under a cooperative agreement between NSF's Computer and Information Science and Engineering directorate and CRA. It has a three-person staff and is led by a council of approximately 20 members—17 from academia and three from industry—who serve for three years. A chair and a vice-chair each serve two-year terms. The council broadly represents the computing field. CCC doesn't designate seats for specialties, such as databases, artificial intelligence, robotics, or programming languages. Nor does it reserve seats for particular universities. There is some overlap between the CCC council and CRA's board, and the CRA board chair approves major CCC decisions.

Besides NSF, CCC has connections with a number of government agencies. It works with the multi-agency Networking and Information Technology R&D coordinating group as well as the National Institutes of Health (NIH), the National Institute of Standards and Technology, the Departments of Agriculture, Energy, and Homeland Security; professional societies ACM and IEEE, and a growing number of companies, including Facebook, Google, Home Depot, IBM, Microsoft, and Visa.

Increasingly, CCC tries to engage and assist early-career researchers, who "really have ideas that can help move the needle and jump us forward." A strong effort is made to diversify participation. This creates the "magic" that moves the needle. "We have anthropologists at our workshops. We have lawyers. We have economists. We have software people at pure hardware conferences."

Two examples illustrate how CCC generates influential ideas: Drobnis cited a call from NIH in 2014 asking for help putting together a workshop on aging-in-place technologies. CCC produced a report, NIH released a request for proposals, and the Veterans' Administration funded a program. Subsequently, the report was cited in a publication by the President's Council of Advisers on Science and Technology. More recently, three CCC AI workshops and "tons of meetings in D.C." resulted in considerable overlap between a consortium report and the Trump administration's AI R&D strategy.

Drobnis acknowledged that "one of our weakest links is engagement with the broad public, and that's a really hard nut to crack, and we are working on that, but it's been very hard for us."

MFORESIGHT: ALLIANCE FOR MANUFACTURING FORESIGHT

Sridhar Kota, a mechanical engineering professor at the University of Michigan, is executive director of MForesight, Alliance for Manufacturing Foresight, a government-sponsored private-sector consortium. With a singular focus on U.S. manufacturing competitiveness, it has attained a broad reach. In the last year, it drew 2,000 experts from 38 states to its workshops, had 20,000 downloads of its reports, and 100,000 website visits.

Created following a 2014 recommendation by the President's Council of Advisors on Science and Technology and a subsequent NSF solicitation, MForesight forecasts upcoming technological trends, identifying "the big ideas that are worth scaling," while researching and helping industry solve immediate challenges. Its work proceeds in four phases: "discover, prioritize, develop, and disseminate." It has a 38-member leadership council—half from industry, 25 percent from academia and 25 percent from NGO's—and can draw on over 60,000 subject-matter experts. Its wide representation includes automotive, aerospace, defense, semiconductor, pharmaceutical, chemical and consumer goods sectors. MForesight also conducts tech-transfer workshops, surveys of manufacturers and researchers, and significant interviews in person or by phone with subject-matter experts. It partners with nonprofits—SME, GMS, MapTech and others—in conducting workshops. Ideas come from multiple sources: researchers from academia and industry, the leadership council; responses generated based on agency requests; surveys; competitions; and watching agencies like DARPA, ARPA-E, NASA, and national labs. In deciding what ideas to pursue, MForesight poses a series of questions: Does an emerging technology have public appeal? Is a challenge cross-cutting, like cybersecurity? What is the impact on our economy, on our national security, or our energy production efficiency? Are there private or federal government investments in this basic research that we can leverage? Then, is there evidence of industry interest and investment? Is it really going to give the U.S. the first-move advantage? (If South Korea or Japan already have it, maybe the U.S. shouldn't work on it.)

Preparing workshops, the consortium makes sure a diverse set of sub-disciplines is represented, starting with a list of 80 possible participants and narrowing it to 35 or 40. It asks: What are the enabling tools? What are the cross-cutting challenges? What are implementation challenges? What are the policy issues? Participants are urged to come up with one or two actionable recommendations that may make a difference. Workshops usually comprise 50 percent industry, 25 percent academia, and 25 percent government.

Some topics are too big for a single workshop. The consortium held seven roundtable discussions around the country last year—totaling 1200 hours of discussion—on Grand Challenges in Manufacturing. "We wanted to address how to rebuild America's industrial commerce, how to create national wealth from modern-day investments, how to ensure financing for hardware startups and scale-ups."

Besides reports, MForesight produces a number of op-eds. The consortium's actionable recommendations have spurred new solicitations and programs at several government agencies, including the Departmens of Energy (DOE) and the Department of Defense (DOD).

BASIC RESEARCH NEEDS WORKSHOPS

Michelle Buchanan, deputy director for science and technology at Oak Ridge National Laboratory, described the rigorous workshop process that underlies the direction of use-inspired basic research at the Department of Energy. The bottom-up, community-driven formula began 20 years ago when the Office of Science, DOE's fundamental research arm, sought to pursue research that better supported the nation's energy needs. Workshops, and the associated reports, look ahead 10 years and beyond, seeking to realize a technology's full potential or meet a Grand Challenge and create something revolutionary. Preparation for the workshop is a 6-9-month, labor-intensive process that starts with choosing chairs, and then panel leads and participants. A breadth of expertise is sought. One example, a workshop on hydrogen, included as co-chairs a physicist-electrical engineer, a chemist, and a solid-state physicist. Themes for each panel are chosen (for hydrogen, they were generation, storage, and utilization). The leadership team consults with industry and applied researchers on where problems or "technical bottlenecks" exist that a basic research approach might solve. A technology status document is produced that factually states "where the community is" in pursuit of a particular research goal and that identifies bottlenecks.

Workshops occupy an intense two to three days. On the first day, during breakout sessions, panels formulate potential priority research directions (PRDs). While typically around 15 people work on each chosen theme, workshops draw a number of observers from national labs and across the government. At day's end, panel leads prepare slides for preliminary reports the next day. "At the end of the first day . . . it's usually chaos. I always tell people it's like entropy happens, and as a workshop chair you're walking between the breakout rooms and you think, 'This will never work,' because everybody's all over the place, but all of a sudden it just kind of coalesces." These reports are meant to inspire (not prescribe, as in a technology roadmap) the community to develop new approaches to address a research challenge and to define the expected impact of the research. After panel reports are presented to the entire workshop and feedback is received on the second day, new slides are prepared showing knowledge gaps and technology needs, PRDs, and examples of areas to be studied. These slides also serve as a basis for communications to the broader scientific community. The closing session on the final day gives a preview of the report on the workshop, which is outlined in detail immediately following the workshop and finalized in the subsequent weeks. DOE's workshop reports "have become a model of how to engage the basic research community in problems associated with our nation's energy agenda."

STAYING AT THE LEADING EDGE

A panel—Michael Gazarik, vice president of engineering at Ball Aerospace; Lisa Teague, head of research and technology at Rolls Royce Indianapolis; and Alton D. Romig, Jr., former vice president and general manager of the Lockheed Martin "Skunkworks" advanced development arm—described approaches to research in the aviation industry.

For Ball Aerospace, membership in NSF-funded research centers is key. "We're going to take whatever we get out of there and then go apply it, go put it into a system," Gazarik said. The company also has relationships with universities. It funds faculty grants, conducts joint research, and sponsors student projects. The latter have the added benefit of aiding recruitment. One successful example of applying basic research is a black carbon nanotube paint that blocks infrared light. Another example is frequency cones used for precise measurements in optical wavelengths. Ball Aerospace operates according to custom roadmaps, developed with its customers, the Department of Defense and NASA, that identify problems in a mission and what needs to be done to solve them. In what the company calls Innovation X, an employee can pitch an idea and compete for a small amount of funding to pursue it. "Maybe the business case isn't there yet . . . but maybe it is something that, down the road, will pave the way." In that way, the research portfolio is not just dominated by the problems of today. For customer funded Independent Research and Development, or IRAD, efforts, "we look for a 40-to-1 kind of ratio. For every IRAT dollar, can we get $40 in sales from the customer side?"

Lisa Teague heads the research and technology group at Rolls Royce Indianapolis, where the global company builds propulsion systems for various applications. She primarily deals with aircraft. Her group has two parts: One, the innovation group, looks for ideas coming from small companies and universities and how Rolls Royce might apply them. Good at thinking outside the box, it's also active in Small Business Innovation Research projects. The other part, the execution group, is funded by the company "to go and develop things that we need for the products of the future." The two parts help each other think about things that otherwise might not come to mind.

Rolls Royce is grappling with how it will be affected by a number of emerging technologies—the digital realm, as well as electrification of flight, hybrid propulsion systems, cybersecurity, autonomy, machine learning and artificial intelligence modeling and simulation. "Those are things that are going outside of where we would consider our traditional strengths have been, but we've got to figure out a way to pull them in, because there are new players out there." Seeking to benefit from cutting-edge research, the company works with a global 31-institution University Technology Center network that includes Purdue, Virginia Tech, and the University of Virginia, and encourages schools to collaborate. Like Ball Aerospace, Rolls Royce holds internal pitch competitions. It also has an innovation portal where an employee can ask the entire company, "Hey, we're looking for ideas on solving this. Does anybody have any ideas?" Ensuring safety requires both patience and "significant investment."

Romig, currently executive officer of NAE, offered perspective from his previous work at Lockheed. He noted that the three companies represented on the panel are "heavily dependent upon government-funded research," which "puts some real restrictions on how you can and cannot spend that money." Independent Research and Development (IRAD) provisions, which Gazarik also mentioned, allow companies to initiate R&D projects of potential interest to the Department of Defense. This was where Lockheed "set a small amount of money aside to do the really far-ranging things." Similar to Ball Aerospace and Rolls Royce, the company also had "a wild-idea plan (in which) people would come in, get 10 minutes to present it, and if it looks like it's of interest, you'd get enough funds to cover yourself for a couple of weeks to see if it could get any legs under it." Besides getting research guidance from DoD and the Intelligence Community, Lockheed participated actively in professional societies and in industry-university consortia. Research priorities were mainly determined by the need to secure America's advantage over an adversary. Lockheed, Boeing, and Northrup Grumman, the aerospace firms that build complete systems, existed in a state of "'coopetition.' One time you might compete with Boeing, and at the same time you're a partner." Lockheed also performed advanced development jointly with component manufacturers, including Rolls Royce, Pratt and Whitney, and General Electric. At times, "we'd both together put money into a university to invest in something longer-term that we thought might be a game-changer."

CONSIDERATIONS IN REALIZING AN ENGINEERING RESEARCH VISIONING ORGANIZATION FOR THE COMMUNITY

Attendees were each assigned to one of six breakout groups to discuss specific aspects to be considered in realizing a research visioning organization. These considerations were formulated as guiding questions to stimulate conversation across four sessions.

FACILITATED BREAKOUT SESSION I

Guiding Question: Informed/inspired by the models presented, what community-driven research models might work best for the broad engineering community? Based on what design principles?

None of the three models presented—MForesight, Computing Community Consortium (CCC), and DOE's basic research preparation—won full support from all six breakout groups. At least two groups clearly favored CCC, and its name came up frequently in discussions. Participants liked its grass-roots character, its success in drawing resources into computer science, its ability "to lead what the next thing is," its effectiveness in communicating the value of machine learning and computation, and its skill in mobilizing different areas of computer science to work together. It also offered "a best practice at getting diversity and inclusion within the computing community." Still, no one seemed to find it a perfect fit for a new community-based engineering research organization. CCC has a narrow constituency, whereas the new group would have to encompass all of engineering, now comprising some 30 disciplines or sub-disciplines. And while CCC has corporate and investor involvement, the model needs to be adapted to bring in more industry, participants said. One group flatly opposed the CCC model, saying it "appears not to scale with our overall vision." This group suggested alternate models, such as a National Engineering and Science Foundation, ASEE, or the American Society of Civil Engineers (ASCE) "and other major engineering societies but with cross disciplines." Others spoke of grafting onto existing organizations or forming an operational arm of NAE.

As to design principles, comments frequently heard were that the proposed organization be broad based, including engineers in academe and industry and thought leaders within the engineering community; interdisciplinary and able to collaborate with fields outside engineering—"Engineering + X"; agile; flexible (both reactive and proactive); capable of rapid response; transparent; and skilled at communicating the value of engineering research to policymakers and the public. "[A suggestion in a group discussion later in the day—during Breakout Session IV—seems relevant to the question of design: It called for online, open-sourced innovation, with loose coordination, that could end up with something robust.]"

Discussions ranged widely, taking in the vision, mission, purposes, constituencies, and prospective audiences of the proposed organization. It was noted by one breakout group that "engineers like to solve challenges," so presenting the proposed organization as tackling a series of challenges was seen as a helpful way to draw in the engineering community. At the same time, the "cross-industry, cross-discipline" nature of the proposed organization will make it hard to secure support for a research direction from all the groups that might have an interest.

The NAE's 14 Grand Challenges and NSF's 10 Big Ideas came up less as a model than as organizing principles, along with over-arching topics, such as sustainability, security, prosperity, and health.

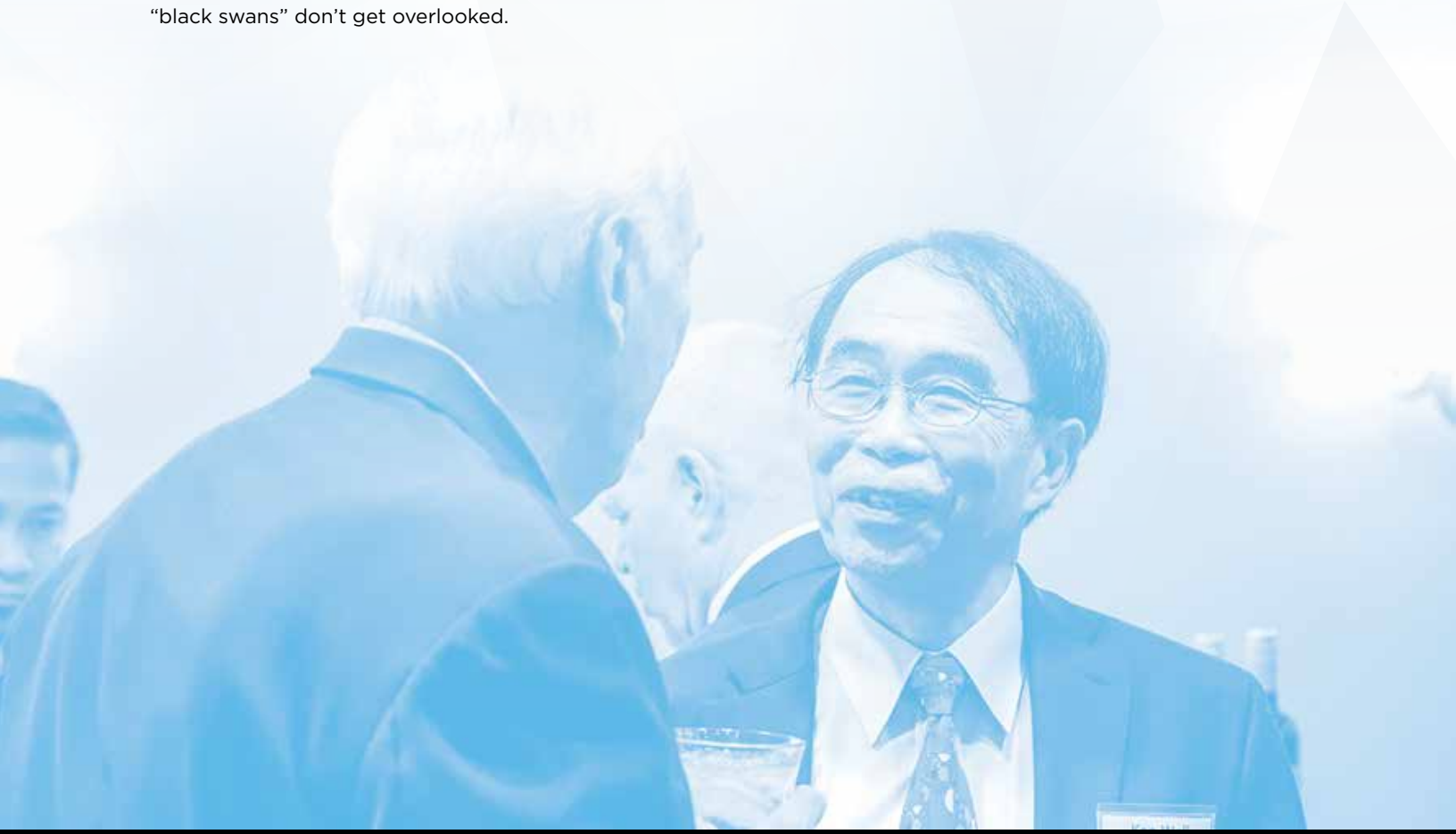
As the organization grows, one group noted, maintaining a unified voice will be a challenge.

FACILITATED BREAKOUT SESSION II

Guiding Question: How do we ensure the incorporation of a diversity of perspectives, including but not limited to technical, organizational and societal dimensions?

The breakout groups addressed diversity in many forms. From academe, participants suggested bringing in non-engineers, such as social scientists, in addition to engineers of all disciplines, tapping all ages, faculty ranks, and experience levels, and small and large institutions in different parts of the country, as well as community colleges. Operational engineers should be included, along with professional and trade societies. Also needed are entrepreneurs and young grad students—"people working in margins where new ideas come in." From the corporate sector, small companies, as well as Fortune 100 firms, investors, and a variety of industries, including consumer products, should be represented. Attention was also given to ensuring gender equity and inclusion of underrepresented minorities. Inclusiveness must also take in outlier ideas so that the rare and unexpected "black swans" don't get overlooked.

Discussions touched on the need to grapple with implicit biases and develop a cultural appreciation of diverse points of view and international diversity. The question of how to find and attract the desired mix of people produced a number of suggestions, including: deans' forums (deans must think outside their own specialties); the NAE's process for selecting early-career researchers for its Frontiers of Engineering symposium and introducing the kinds of projects that inspire millennials; NASA's International Space University, which brings together engineers and scientists, but also sociologists, psychologists, artists, and reporters, creating space for discussion of societal impacts; and a network environment to let ideas come in organically. Sohi Rastegar, of NSF, described the blind strategy for choosing Emerging Frontiers in Research and Innovation (EFRI) topics. One result was research on quantum communication technologies. It was noted that giving every voice a chance to be heard doesn't mean that every view is given equal weight.



FACILITATED BREAKOUT SESSION III

Guiding Question: How best do we validate model(s) we've identified with the engineering community at large?

Once a model is set, most groups would look first to existing organizations, including the NAE (and its Frontiers of Engineering symposium), professional societies and trade associations, and the Council of Engineering and Science Society Executives (CESSE)[1] for endorsement, along with university vice presidents for research, deans, and ASEE's Engineering Research Council. Securing the trust of stakeholders is essential. A steering group might be formed of leaders who can speak to industry, including corporate chief technology and chief information officers, academics, economists, Nobel laureates, representatives of major research centers, and high-level government staffers. University partnerships with industry were suggested as a worthwhile vehicle for communication. There should be outreach to conference boards and groups of CEOs, vice presidents, and company directors. "Go on a promotion tour," one group suggested, and make sure to reach out not just to heads of organizations but junior members. An effort should be made to capture the public's imagination as well. It would help to have a champion on Capitol Hill or at the White House Office of Science and Technology Policy. Broader government support might be sought at the Department of Defense and the National Institute of Standards and Technology. The comment was made, "If you get lower-level buy-in but don't have upper level (NAE, NSF) then the whole idea is a dead end." Academics will likely want to join if there is support from NSF. Community leaders can help identify others who could give the project momentum. A test case project from the Grand Challenge "buckets"—*sustainability, security, prosperity,* and *health*—could be a vehicle for communication and gaining support and also serve as a pilot to test the model. Publications and the citations that result from research inspired by the new organization would demonstrate quality and help the organization gain credibility. It will be important to set success criteria for the chosen model—"How do we gauge the impact?"—and follow up with assessments. Be prepared to change: "If the model doesn't excite participation outside of the usual group," then it needs another look. Finally, the broader community must be encouraged to stay engaged. A way to do that is show products—"something people can touch."

INSIGHTS OF PARTICIPANTS FROM INDUSTRY

Industry representatives were asked what value they saw for their sector in an independent organization that would recommend research priorities. They made a series of points:

Several saw an advantage in being able to attract talent, such as students participating in NSF-funded research, through the new organization. A retired top executive of an automotive organization looked forward to an entity that would "envision and define the competencies and the skills that we're going to need to be competitive and be innovative and remain leaders of innovation." A participant who recently joined a biotech startup imagined entrepreneurs being inspired to launch new companies based on research ideas put forward by a visioning group. Having those ideas backed by a consensus of the engineering community would give investors confidence. The representative of a large company anticipated seeking out "clusters of expertise that we can then work together with" through the new entity—particularly in connection with longer-term (five-plus years) projects. "We really believe that we can develop much faster when we work together with academia." For a large tech firm, the advantage would be "an ability to react quickly and to be able to encourage the research and the development of students" performing research for which there is a recognized need. A participant from a major chemical manufacturer spoke broadly of the opportunity "to be connected with what's the future." Communities, such as those that would form around the new organization, "create those small

[1] With the recent demise of the American Association of Engineering Societies, CESSE is the sole legal entity representing engineering society representatives; it also includes science society representatives.

signals" of potentially revolutionary developments. A representative of an aerospace company hoped to see results that would benefit all companies, even if they're not tapped for direct investment.

FACILITATED BREAKOUT SESSION IV

Guiding Question: How best do we pursue implementation of the model(s)?

Breakout group participants were divided on whether NSF should move ahead quickly to seek proposals for a new engineering research organization or create an interim task force or panel to figure out next steps and build momentum. One reason for a cautious approach is that not all participants were convinced a strong justification exists for the proposed entity. "The first step is to see if this has legs," one participant said. Notes from one breakout group, addressing how the organization would be funded, stated: "The vision might not lead to a specific hook. . . . The question is if there is an actual opportunity."

A task force or panel would need a charter and credible participants who are both good listeners and good communicators, some participants thought. It would seek buy-in from "a big cross section of the community" and/or "raw engagement with the public" on the kinds of challenges engineering researchers should address. One group urged additional input from small companies—a sector that lacked strong representation at the workshop. A less ambitious role for the task force would be to focus on what they want to see in proposals and how to generate them.

As an alternative to a task force, one suggestion was for the Engineering Directorate's Advisory Committee, or an undefined "overarching entity," to assume that role. Existing NSF methods, such as a request for information, could collect the engineering community's view of the new organization and how it should proceed. One group said a call should be issued for a "group of organizations that come together with a recognized challenge to be solved."

A number of participants supported developing a vision statement. As one group noted, a "well-articulated vision can attract a variety of constituencies," offer a "better chance to identify emerging research ideas" and get a "range of input from a lot of different sources via this approach."

One participant argued for moving ahead quickly but on an experimental basis: "Do a test study, get the results from the implementation of the model, prove that it will generate new ideas." When a funding source is identified, a request for proposals (RFP) could be issued that says, "We want to develop an engineering visioning process, and we want to request proposals and we want you to be a part of it." Thinking along similar lines, others in the same group spoke of a "narrow focus across a very large set of stakeholders/disciplines, [and] multiple mini-pilot studies." The RFP could list four potential "challenge" topics, but could pick fewer depending on responses. Instead of an RFP, there could be a shark-tank approach, hack-a-thon, "something that involves the community" and can collect one-off ideas.

The idea of starting small also appealed to a separate breakout group—"but not with a particular community because [then] the broader community won't be engaged." This group also said the organization should be light on administration "and organically grown but with boundary conditions."

One group wondered about "ownership" of the proposed organization and how much independence it would have, given that NSF would fund it. A participant familiar with NSF's thinking suggested that the agency was willing to take a hands-off approach; it initiated the process because the community hadn't done it. Others wondered whether NSF would even have the money to pursue the project; outside funding or a new congressional appropriation might be needed. It was thought likely that 8-10 existing organizations might seek to create the new entity, including ASEE, NAE, and the Science and Technology Policy Institute.

Whatever the process for moving forward, one participant said, "We will need to 'build the plane while we're flying it.'"

FINAL THOUGHTS

Opening the final day of the Visioning Summit, co-chair Deborah Crawford reflected on what would distinguish a new organization intended to generate bold engineering research ideas. One important feature is the "opportunity to give (an) independent voice to the engineering research community" and "meaningfully include diverse communities in shaping the voice of the engineering research community" in a way that is independent of all the organizations. Referring to Dan Mote's example of the starfish as an organizational model, she said, "It actually is creating powerful leaderless organizations who speak in powerful ways."

The Visioning Summit served as a first step in giving an independent voice to the engineering community and finding a way to unite behind a future research direction. Participants did not end up speaking with a single voice—either about which of the organizational models they preferred or about next steps. The format wasn't structured to come up with clear consensus-based recommendations and none emerged. Instead, breakout groups generated a variety of options and ideas. But the two days of intense discussions demonstrated strong interest among a varied group of engineers representing academe and industry in pursuing "research for the betterment of society and the planet," as cited by Dawn Tilbury. Summit attendees also enthusiastically embraced the goals of hearing from a diversity of voices and pulling together multi-disciplinary talents to confront grand challenges.

APPENDIX I - WORKSHOP AGENDA

TUESDAY, JULY 16, 2019

6:30 PM – 8:00 PM	**WELCOME AND OVERVIEW** **Dawn Tilbury,** Assistant Director for Engineering, NSF [Remarks]

WEDNESDAY, JULY 17, 2019

8:00 AM – 8:30 AM	**REGISTRATION**
8:30 AM – 9:00 AM	**OPENING SESSION** Welcome and Goals for the Day **Lance Davis,** former VP for R&D, Allied Signal, Co-Chair, Summit Steering Committee **Deb Crawford,** VP for Research, GMU, Co-Chair, Summit Steering Committee **Norman Fortenberry,** Executive Director, ASEE **Sohi Rastegar,** Chair, NSF/ENG Working Group
9:00 AM – 10:00 AM	**NATIONAL ACADEMY OF ENGINEERING GRAND CHALLENGES FOR THE 21ST CENTURY** **C.D. (Dan) Mote, Jr.,** Past President, National Academy of Engineering [Slides]
10:15 AM - 11:45 AM	**GENERAL SESSION 1: EXISTING COMMUNITY-DRIVEN RESEARCH MODELS AND CASE STUDIES** Chair: **Deb Crawford** THE COMPUTING COMMUNITY CONSORTIUM *https://cra.org/ccc/about/* **Ann W. Schwartz Drobnis,** Director, CCC [Slides] MFORESIGHT: ALLIANCE FOR MANUFACTURING FORESIGHT *http://mforesight.org/about-us/#whatwedo* **Sridhar Kota,** Executive Director, MForesight [Slides] BASIC RESEARCH NEEDS WORKSHOPS *https://science.osti.gov/bes/Community-Resources/Reports* **Michelle Buchanan,** Deputy Director for Science and Technology, ORNL [Slides]

11:45 AM – 12:30 PM	**GENERAL SESSION 2: "STAYING AT THE LEADING EDGE"** **Michael Gazarik,** Senior Vice President of Engineering, Ball Aerospace **Alton D. Romig, Jr.,** Executive Officer, NAE (former Vice President and General Manager of Lockheed Martin Advanced Development Programs) **Lisa Teague,** Head, Research and Technology, Rolls Royce
12:30 PM – 12:45 PM	**Q & A FOR GENERAL SESSION 2**
2:00 PM – 2:45 PM	**FACILITATED BREAKOUT SESSION 1** Chair: **Norman Fortenberry** Informed/inspired by the models presented, what community-driven research models might work best for the broad engineering community? Based on what design principles?
3:00 PM – 3:30 PM	**BREAKOUT SESSION 1 REPORTS**
3:45 PM – 4:30 PM	**FACILITATED BREAKOUT SESSION 2** Chair: **Lance Davis** How do we ensure the incorporation of a diversity of perspectives, including but not limited to technical, organizational and societal dimensions?
4:45 PM – 5:15 PM	**BREAKOUT SESSION 2 REPORTS**
5:15 PM – 5:30 PM	**GENERAL SESSION 3: FINAL COMMENTS FOR DAY 1 AND CHARGE FOR DAY 2** **Sohi Rastegar,** NSF

THURSDAY, JULY 18, 2019

8:30 AM – 9:00 AM	**GENERAL SESSION 4: SUMMARY OBSERVATIONS FROM DAY 1/CHARGE FOR DAY 2** **Deb Crawford,** VP for Research, GMU, Co-Chair, Summit Steering Committee [Slides] **Lance Davis,** former VP for R&D, Allied Signal, Co-Chair, Summit Steering Committee
9:00 AM – 9:45 AM	**FACILITATED BREAKOUT SESSION 3** Chair: **Sohi Rastegar** How best do we validate model(s) we've identified with the engineering community at large?
9:45 AM – 10:15 AM	**BREAKOUT SESSION 3 REPORTS**
10:30 AM – 11:15 AM	**FACILITATED BREAKOUT SESSION 4** Chair: **Deb Crawford** How best do we pursue implementation of the model(s)?
11:30 AM – 12:00 PM	**BREAKOUT SESSION 4 REPORTS**
12:00 PM – 12:15 PM	**CLOSING SESSION: FINAL REFLECTIONS AND NEXT STEPS** **Deb Crawford,** VP for Research, GMU, Co-Chair, Summit Steering Committee **Lance Davis,** former VP for R&D, Allied Signal, Co-Chair, Summit Steering Committee **Sohi Rastegar,** Chair, NSF/ENG Working Group

APPENDIX II - REMARKS BY DR. DAWN TILBURY

EVENING OF JULY 16, 2019

Welcome everyone, and thank you for being here tonight. I'm Dawn Tilbury, the Assistant Director for Engineering at the National Science Foundation. I'm excited to see you all here, believe we're going to have a productive and exciting time over the next couple of days.

First, I'd like to thank everyone who has worked to put this together. They've put a tremendous amount of time and energy into making this event happen. In particular, I would like to recognize Deb Crawford and Lance Davis, our co-chairs for this summit. I also want to thank ASEE, led by Norman Fortenberry and his team, for organizing our sessions.

We have a great lineup of speakers who have come from all around the United States to be with us and share their insights, and we thank them for their time and their expertise. Finally, thank you to the NSF ENG working group for Visioning. Their efforts and time have culminated in bringing us all together today. I'd also like to thank all of you for being here. You come from all sectors- industry, academia, government, and professional societies. Having all of your perspectives here matters a great deal to us.

I would like to begin by offering for your consideration some remarks regarding visioning.

There are lots of ways to define visioning. For our purposes, visioning may be viewed as imagining how engineering will shape and drive the betterment of the future of our society and our planet. I've heard it said that scientists study the world that we have, while Engineers create the world we want. How do we define the areas where basic research in engineering is needed to create that future world? Note that the purpose of this workshop is not to identify those areas specifically, there will be future workshops that get into the specific directions. We want the visioning activity this week to lay out a plan or a path to bring the engineering community together to develop these future research directions that will place our nation in a leading position to achieve and realize a better future for us all.

Our own vision for this visioning effort is that the *Engineering Community will speak with a unified voice on bold and high impact fundamental research directions that will drive rapid and efficient response to emerging opportunities and areas of national need.*

Visioning matters to us. NSF funds more than 40% of fundamental engineering research at academic institutions. We gather lots of input from the community about where we should go next in the research endeavor, through workshops, RFIs, and bringing members of the community into NSF as rotators, but we think there's opportunity to do better here, and really to bring the whole community together to outline what those future directions are.

Our goal for this summit was to convene key constituencies of the engineering community—that's all of you —to discuss possible mechanisms or organizational structures that will enable the collective identification and definition of promising emerging engineering research opportunities and directions. A key thing to remember here is that this effort will benefit the whole engineering community.

Visioning exercises in engineering and elsewhere are not without precedent. The National Academy of Engineering led an effort to identify Grand Challenges, which have provided us with excellent ideas and galvanized the field. NSF has a variety of internal initiatives that it uses to identify and shape the field. NSF's Big Ideas represent a vision for the future of research, while NSF 2026 is meant to engage the broader public in driving the formulation of new questions and identification of new challenges. And in engineering, our Emerging Frontiers in Research and Innovation program has—with your help—pushed the boundaries of what is possible in fundamental engineering research.

What makes this Visioning effort distinctive is that while it potentially will be funded by NSF, it will be driven by an independent community based group. This aligns with formidable efforts in other fields. The computer science and engineering community led an effort to articulate compelling research opportunities via the

Computing Community Consortium. You'll hear more about that tomorrow from Ann Schwartz Drobnis, the director of the CCC.

The Department of Energy Office of Science uses its Basic Research Needs Workshops in a similar fashion, and I'm sure some of you are familiar with their highly regarded reports. We'll have a chance to learn more about this effort from Michelle Buchanan, the Deputy Director for Science and Technology at Oak Ridge National Laboratory. And in manufacturing, we have MForesight: the Alliance for Manufacturing Foresight, which works to understand and prepare for the future of manufacturing by engaging a broad cross-section of the manufacturing community. We're fortunate to have Sridhar Kata, the executive director of MForesight, here with us tomorrow to tell us more about it.

There are many other examples - the Decadal Surveys on Astronomy and Astrophysics, innovation challenges, and more. But you get the idea. We want to achieve something here that is ambitious and maybe even a little audacious. How do we, as an engineering community, see the future? How will we shape the future? And how will we set the agenda now and for years to come?

And that's why we're all here today. You notice on your agendas that there are several breakout sessions throughout the course of the two days that will give you ample opportunity to work collaboratively in smaller groups to generate ideas, think creatively, and delve into deeper discussions on various aspects of the visioning effort.

I'd like to challenge you to think big during your time here. We want this gathering to be productive and game-changing for each of us and our communities. We have some things in mind for what we hope to achieve as outputs from this gathering. First, we'd love to increase connectivity among us all as engineering community stakeholders for the purpose of visioning. We would also like us to share community best practices for identifying research opportunities - what are we already doing well? How we can do more of it, and how can we make it even better? But most importantly, we want to learn about your best ideas for possible mechanisms or organizational structures that will achieve visioning for the engineering community writ large.

So that's our mission for the next two days: to connect, to share, and to think of bold new ideas. This is not a small task, but I am confident we are all up to the challenge.

I imagine that such a big task leaves us with lots of questions. I'd like to now open the floor to learn what is on your mind as you embark on this endeavor. Please feel free to share any thoughts or questions that are on your mind - I'd be more than happy to answer your questions.

Thank you.

APPENDIX III - LIST OF ATTENDEES

ATTENDEE	ORGANIZATION
Billy Bardin	Dow Chemical Company
Steven Baxter	Arkema Inc.
Tony Boccanfuso	University-Industry Demonstration Partnership (UIDP)
David Bourell	University of Texas at Austin
Andrew Brown, Jr.	Diamond Consulting
Amy Clarke	Colorado School of Mines
Duncan Coffey	DuPont de Nemours, Inc.
Glen Daigger	University of Michigan
Christopher Geiger	Lockheed Martin
Joseph Hartman	Institute of Industrial and Systems Engineers
Kayleen Helms	Intel
Sheldon Jacobson	Institute for Operations Research and the Management Sciences (INFORMS)
Leah Jamieson	Purdue University
Chris Jelenewicz	Society of Fire Protection Engineers (SFPE)
Jelena Kovacevic	NYU Tandon School of Engineering

ATTENDEE	ORGANIZATION
Ramayya Krishnan	Institute for Operations Research and the Management Sciences (INFORMS)
Brian Landes	Society of Plastics Engineers
Ron Latanision	Exponent, Inc.
John Lesko	Virginia Tech
Guru Madhavan	National Academy of Engineering
Roger McCarthy	McCarthy Engineering
Steven McKnight	Virginia Tech
Brian Meacham	Society of Fire Protection Engineers
Mark Meili	The Procter & Gamble Company
Leslie Momoda	HRL Laboratories (formerly Hughes Research Laboratories)
Kimberly Ogden	University of Arizona
Todd Osman	Materials Research Society
Jonathan Owen	General Motors
Darryll Pines	University of Maryland
Hari Pujar	Moderna Therapeutics

ATTENDEE	ORGANIZATION
Art Pyster	George Mason University
Adam Rasheed	Sentient Science
Michael Richey	The Boeing Company
Ian Robertson	College of Engineering, University of Wisconsin-Madison
Kent Rochford	SPIE, The International Society for Optics and Photonics
Jamie Rogers	Institute of Industrial & Systems Engineers
Jim Rossberg	American Society of Civil Engineers
Maxine Savitz	Honeywell
Darlene Schuster	American Institute of Chemical Engineers
Anne Shim	BASF
Cristina Thomas	3M
Jay Walsh	Northwestern University
Turner Whitted	TWI Research LLC
Jeffrey Yu	Northrop Grumman Corporation

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