Subra Suresh Discusses Strategies to "Sustain the U.S. Innovation Engine"

Lynne Robinson

Subra Suresh, director of the U.S. National Science Foundation (NSF), has been selected to present the ASM/TMS Distinguished Lecture in Materials and Society at the Materials Science & Technology (MS&T) 2011 Conference, scheduled October 16–20 in Columbus, Ohio. He will also be one of three speakers at an all-conference plenary session on Grasping Excellence: Opportunities for Science and Engineering Research, Education, and Workforce Development in the United States. At that point, Suresh will have completed his first year leading the only U.S. federal agency charged with advancing all fields of fundamental science and engineering research and education. He was inducted as a TMS Fellow in 2000, and has been elected a fellow or honorary fellow of all the major materials society in the United States and India.

Prior to his confirmation as NSF director, Suresh served as Engineering School dean and Vannevar Bush Professor of Engineering at the Massachusetts Institute of Technology (MIT). He joined MIT's faculty in 1993 as the R.P. Simmons Professor of Materials Science and Engineering. During his more than 30 years as a practicing engineer, he held joint faculty positions in four MIT departments, as well as appointments at the University of California at Berkeley, Lawrence Berkeley National Laboratory, and Brown University.

Suresh has received numerous international awards and honors throughout his career, including the The Padma Shri Award (2011) from the President of India, Indian Science Congress General President's Award (2011), Society of Engineering Science Eringen Medal (2008), European Materials Medal (2007), and Acta Materialia Gold Medal (2006). He has published more than 230 research articles in international journals and more than 18 U.S. and international patent applications bear his name. He has also authored or co-authored several books that are widely used in materials science and engineering, including *Fatigue of Materials* and *Thin Film Materials*.

Subra Suresh, director of the U.S. National Science Foundation, will present the ASM/TMS Distinguished Lecture in Materials and Society at MS&T 2011, October 16-20, Columbus, Ohio. (Photo credit: Sandy Schaeffer, National Science Foundation.)

Initially educated as a mechanical engineer, Suresh eventually branched into materials science and the biosciences, and his work is marked by a blending of these fields. His most recent efforts tackled the biomechanics of red blood cells under the influence of diseases such as malaria. In 2006, *Technology Review* magazine selected Suresh's research on nanobiomechanics as one of the top 10 emerging technologies that "will have a significant impact on business, medicine or culture."

This interdisciplinary approach to discovery continues to inform Suresh's work at the NSF. "Through these experiences, I gained a vantage point for looking at things with a broader perspective than I would have had if I'd stayed in one field," he said.

As a preview to his lecture at MS&T 2011, Suresh offered the following insights into the NSF's current priorities for ensuring the strength and effectiveness of the U.S. science and engineering enterprise, and the role that materials science and engineering will play in these efforts.

Q. Your Distinguished Lecture at MS&T 2011 focuses on building the science and technology workforce of the United States. Could you share a few of the key points that you are planning to make?

A. We have an opportunity to make a real difference in sustaining the U.S. innovation engine by working to diversify the science, technology, engineering, and mathematics (STEM) education and workforce pipeline However, data recently released by NSF's National Center for Science and Engineering Statistics indicate that the percentage of underrepresented minorities earning science and engineering degrees is declining at Historically Black Colleges and Universities (HBCUs) and at high-Hispanic-enrollment institutions. This is bad news, given that minority-serving institutions have been the nation's powerhouses for generating degrees in science and engineering for underrepresented minorities. The bad news is amplified when you consider that, by 2040, we will

be a nation of a majority of minorities who are now severely underrepresented in the scientific workforce. We cannot wait another 10 to 20 years to address this issue.

I'm also concerned about the retention of women in the STEM enterprise. In 2009, 72 percent of all valedictorians in U.S. high schools, public and private, were women. Last year, female college graduates outnumbered males by 20 percent, and that difference is increasing. In addition, the growth in the last decade in science and engineering Ph.D.s for U.S. citizens and permanent residents was primarily due to the participation of women.

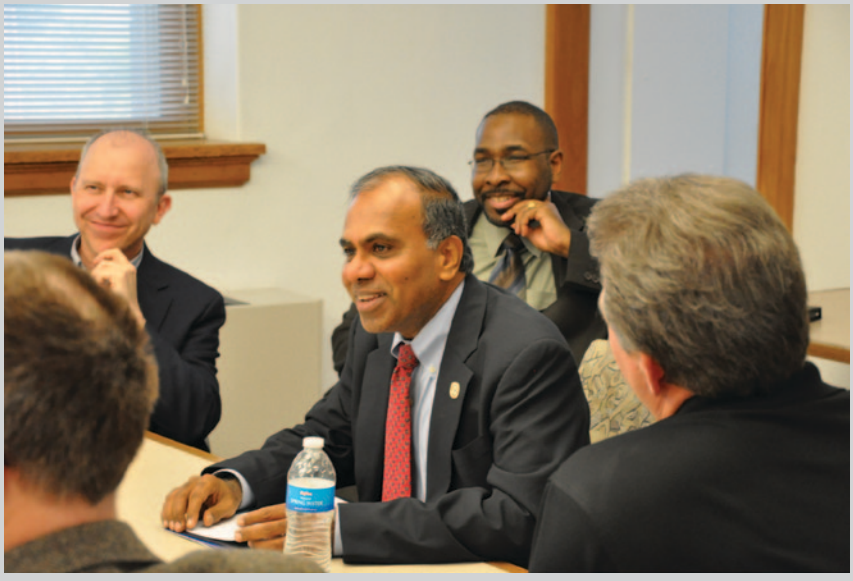
Yet, in 2006—the most recent year for which we have data on women in the workforce—women comprised only about 26 percent of the workers in science and engineering occupations. Why is there such a drop-off in the STEM workforce when we have bright, highly motivated female valedictorians wanting to do science, high numbers of women in college, and women getting Ph.D.s in science and engineering in increasing numbers?

There have been a number of studies into this very complex issue, including recent, comprehensive ones from the Center for American Progress and Berkeley Law. They have identified many factors that contribute to this situation, with the most compelling related to child-bearing and raising a family. The Berkeley Law study actually provides family-friendly recommendations for universities and for national agencies to partner in sensible solutions.

For years, NSF has been working to engage students from underrepresented groups at all levels, so that those with STEM degrees and in STEM careers can be truly reflective of our diverse society. We also cannot afford not to harness the talent of people from all groups in the STEM enterprise. Diversity of our STEM workforce is critical, especially as it relates to the changing demographics of the nation and the increasing competition in the global marketplace.

Q. Related to your Distinguished Lecture topic, the proposed NSF Fiscal Year (FY) 2012 budget included a request for $60 million for new approaches to STEM education. What types of innovations are you hoping this will encourage?

A. Clearly the world has changed since many of us were in school. Students are much more technologically savvy and have access to a wider range of information outside of the classroom. We also know much more about how they learn. Schools of education and school districts are recognizing that their preparation and support of teachers should reflect this reality.



NSF Director Subra Suresh leads a STEM education roundtable at Iowa State University held in April 2011. (Photo credit: Lee Herring, National Science Foundation)

Research from NSF's Science of Learning Centers shows that only a small percentage of a person's life is spent in formal education, while learning outside of school accounts for the rest. This blurring of lines between formal and informal education is significant, with students moving smoothly from one world to the other. Through the Teacher Learning for the Future (TLF) program, we aim to identify best practices to improve the training of pre-service, in-service, and future generations of teachers as they adapt to these new teaching challenges. We are hoping to see cutting edge proposals to reflect approaches that are in tune with today's learners. This investment will strengthen the skills of 250,000 current teachers, as well as the number of additional teachers qualified to teach mathematics and science in our public school systems.

Q. What about initiatives focused on teaching at the college level?

A. When students go on to college, we see that many who start out in STEM disciplines abandon them to pursue other fields. We know that most leave in good standing, but often don't feel welcomed or valued during their beginning studies—They get turned off by poor teaching.

Through the Widening Implementation and Demonstration of Evidence-based Reforms (WIDER) program, NSF will support research, education, and demonstration projects designed to promote the widespread adoption of improved undergraduate instructional practices. WIDER will target the teaching of all undergraduate STEM courses and the teaching practices of all faculty in the STEM departments at funded institutions.

We're looking at what we know about effective teaching at this level and asking why it's difficult to get those approaches into the wider community at colleges and universities. This is going to be a broad effort of both our educational and research directorates to motivate the academic community, including large research institutions, to find better ways to engage students from the beginning—to attract them, help them learn, and keep them in STEM.

Community colleges are an important part of this work. We already have a program called Advanced Technological Education (ATE) which has been very successful in supporting community colleges to train technicians. We want to look at not only ATE's success in getting students into career pathways, but also recruiting more interested students into four-year colleges and graduate schools. We also want to look at innovative ways to develop better relationships between two-year and four-year institutions.

Community colleges are often an overlooked portion of the professoriate. What kind of professional development can we be providing for community college faculty? How can we offer them research experiences that will enrich their teaching? What can four-year and research intensive institutions learn from them about how to best help and support undergraduate students? These are the kinds of opportunities that offer a direct benefit to students and could help them make a smooth transition into a four-year college.

Finally, through a new program, the Transforming Broadening Participation through STEM (TBPS) portfolio, we will expand the agency's efforts to engage underrepresented groups. The program will forge partnerships among scientific research centers and entities with institutions committed to broadening participation, including Hispanic-serving institutions. This creative synergy of diverse ideas and perspectives is essential to enabling the transformative research that invigorates our nation's science and engineering enterprise.

Q. Under your leadership, several NSF initiatives have evolved that encourage cross-disciplinary science. Why, in your opinion, is it important to emphasize this research approach?

A. One of my goals is to find ways to foster greater interdisciplinary work both within NSF and in the NSF-grantee community. Most of the problems we face today in science and society are highly complex. Fortunately, discoveries emerging from research at the intersections of traditional disciplines have given us a deeper and broader understanding of nature's pervasive complexity and greater insight into options for responding to these problems. The promise of interdisciplinary research is not simply an academic issue, but involves the broader relationship between science and society.

NSF has been organized around traditional disciplines for many years, but we have recently launched a number of activities that move beyond discipline-specific boundaries in order to encourage integrated, interdisciplinary research.

In the FY 2012 budget, for instance, the new Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE) program is intended to catalyze interdisciplinary research, particularly in emerging areas of science and engineering. We are particularly interested in identifying, supporting, and nurturing innovative and transformative ideas that lie outside of traditional disciplinary spheres. INSPIRE will address critical evaluation issues by implementing a system to assess the impact of interdisciplinary awards and will also enable NSF directorates and program offices to work together in more cohesive ways.

Q. What particular challenges or considerations must be addressed when embarking on interdisciplinary endeavors? What is NSF's role in addressing these challenges?

A. The grand challenges of creating a sustainable human future are complex issues that require inputs from many disciplines across the human and natural sciences. Accordingly, a significant component of the proposed NSF FY 2012 budget is the Science, Engineering, and Education for Sustainability (SEES) investment area. Research in this portfolio focuses broadly on sustainability, including priorities in fundamental science research into clean energy, water, environment, transportation and infrastructure. In addition, SEES investments will improve our ability to rapidly respond to catastrophic events, such as power grid disruption, floods, or extreme weather. SEES addresses these challenges through a systems-based approach to understanding, predicting, and reacting to change in the linked natural, social, and built environment.

Similarly, BioMaPS, or Research at the Interface of the Biological, Mathematical and Physical Sciences and Engineering, seeks to integrate research from those disparate fields to lead to new theoretical and experimental techniques. The novelty of the BioMAPS approach is the strategic investigation of living systems across scales from atoms and molecules to organisms to environment, and the application of that knowledge to develop new fundamental understanding and new technologies.

One of the biggest challenges to facilitating collaboration among life and physical scientists is providing a venue where communication barriers among the disciplines are broken down and the nurturing of common interests can take place. Several of NSF's Science and Technology Centers, such as the new BioComputational Evolution In Action Consortium at Michigan State University, provide fertile ground where life scientists work with computer scientists and engineers to develop self-replicating, self-correcting technologies to solve extremely complex problems in genome organization, social behavior, computer security, and robotics design.

By providing substantial funding to train students in interdisciplinary science—from undergraduate courses through graduate degree programs—our Science and Technology Centers likewise play a key role in developing the STEM workforce needed to address the increasingly complex issues that society faces. These interdisciplinary research centers also help motivate university administrators to reward faculty for breaking out of disciplinary boundaries and collaborating across disciplinary departments.

Q. What are NSF's key funding and programming priorities that might be of particular interest to materials scientists and engineers?

A. Materials research is pervasive throughout much of the foundation, with the most relevant activities being found in the Directorates of Mathematical and Physical Sciences (e.g., Divisions of Materials Research and

Chemistry) and Engineering (e.g., Divisions of Chemical, Bioengineering, Environmental, and Transport Systems; Civil, Mechanical, and Manufacturing Innovation; Electrical, Communications and Cyber Systems). While each of the divisions has a different emphasis, their work is coordinated and complementary, spanning from discovery of new phenomena and materials to the efficient and effective use of engineering materials in applications. Supported research includes theory, simulation, modeling and experiment. Many efforts combining one or more of these areas.

I have already touched on SEES and BioMaPS as areas of interest for materials scientists and engineers in FY 2012. Also important to the materials community is NSF's focus on the Cyber-infrastructure Framework for 21st Century Science and Engineering (CIF21). This initiative aims to develop and deploy a comprehensive, integrated, sustainable, and secure cyberinfrastructure to accelerate research and education and new functional capabilities in computational and data-intensive science and engineering. This will transform our ability to effectively address and solve the many complex problems facing science and society. CIF21 efforts will serve to support materials scientists and engineers who are expected to rely increasingly on Integrated Computational Materials Engineering (ICME) approaches in their work.

Materials researchers may also be interested in NSF's contribution to the multi-agency National Nanotechnology Initiative (NNI). For FY 2012, there will be three signature NNI Initiatives: Nanoelectronics for 2020 and Beyond, Sustainable Nanomanufacturing, and Nanotechnology for Solar Energy Collection and Conversion. Of course, the NSF interest in nanoscale science and engineering extends beyond these initiatives. Furthering our knowledge of the novel properties emerging at the nanoscale and determining how to control and manipulate them are yielding new discoveries that are independently exciting and an essential component to the success of these initiatives collectively.

I would also note that the NSF's FY 2012 budget request encompasses increases for materials science and engineering research. For example, in the Division of Materials Research, the request includes increases in the commitment to individual investigator programs and CAREER awards, as well as continued support to interdisciplinary research centers. This program has been restructured, however, in response to the 2007 National Academy of Science report, *The NSF's Materials Research Science and Engineering Program, Looking Back, Moving Forward*, and now has two tracks: Centers composed of multiple research themes, and Materials Interdisciplinary Research Teams (MIRT) representing collaborative efforts with a single research theme. Originally, the name of these centers was going to change, but following an appeal from the community, it has been decided to retain the established and recognized Materials Research Science and Engineering Centers (MRSEC) name. The competition under the new format is ongoing and we will be evaluating it after the competition is complete.

Q. Given the current economic climate, what case needs to be made for the value of basic research?

A. This is a time that we, as a nation, must maintain a long-term perspective on the need for science, particularly when we have competition from societies with large populations. President Obama has been a firm advocate for the value and promise of basic research and the potential it has to increase the well-being and prosperity of all Americans—and all people around the globe. America's economic prosperity and global competitiveness depend on innovation that comes from new knowledge, new technologies, and a highly skilled and inclusive workforce. Keeping the research going, especially in difficult economic times, is fundamental to our future prospects.

Q. What can be done to build public understanding and support of the importance of funding research initiatives?

A. The science and engineering communities need to work together to demonstrate that a kernel of research has the potential to blossom into multiple innovations. These, in turn, can burgeon into new industries and create waves of new jobs. Discoveries can also help us respond to important national issues, from renewable energy to advanced manufacturing.

Q. Given that you are a long-time member of TMS, what actions or initiatives can TMS and societies like it undertake to address the critical issues facing their professions?

A. Professional societies can play a major role attracting young people to STEM fields, and then engaging young and mid-career people in leadership roles within the organization. This, in turn, can help them become leaders in their fields.

NSF is also always open to innovative arrangements that promote discovery and promise economic benefits.

Q. What lessons have you learned so far in your role as NSF director?

A. I have realized that basic research is more critical to the future of the United States than ever before. NSF is a great organization, and every day I discover some great work that NSF has helped to create. The foundation is well-positioned to stimulate innovative research that connects the science and engineering enterprise with potential economic, societal, and educational benefits. This is critical at a time when economic and environmental challenges are increasingly at the forefront of decision-making. NSF's high-risk and potentially transformative investments will continue to lead the way for important discoveries and cutting-edge technologies that will help keep our nation globally competitive, prosperous, and secure.

For additional information on MS&T 2011, go to the MS&T 2011 home page at http://www.matscitech.org. *Registration for MS&T 2011 is now open and can be completed online at* http://www.matscitech.org/register.

Lynne Robinson is a news and feature writer for TMS.