Testimony of

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on
NSF's Role in Advanced Manufacturing

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Chairman Wolf, Ranking Member Fattah, and Members of the Subcommittee, it is my privilege to be here with you today to discuss the National Science Foundation's role in advanced manufacturing.

Introduction

In February, the National Science and Technology Council in the Executive Office of the President released a "***National Strategic Plan for Advanced Manufacturing***." Focusing on means of acceleration of innovation for advanced manufacturing, this report identifies five key objectives for federal agencies involved in supporting advanced manufacturing. While NSF plays a role in all five objectives, of particular importance for NSF are the contributions we can make in (a) basic research relating to advanced manufacturing, (b) supporting the necessary educational background for a growing advanced manufacturing sector, and (c) leading by example in important partnership programs among academia, government and industry focused on advanced manufacturing. We play a critical role in investing in basic research which serves as the foundation for advancements in many fields, including manufacturing. And, realizing that innovative ideas come from an innovative, talented workforce, we invest in critical programs that support education in key areas of science and engineering. In many cases, both in research and in education, we accomplish these objectives through active partnerships with other agencies and industry.

NSF's Historical and Present Investments in Basic Research and Education Relating to Advanced Manufacturing

Few areas of research hold as much potential for significant short-term and long-term economic impact as research in advanced manufacturing. Rather than a "refinement" of traditional manufacturing processes, advanced manufacturing involves new methodologies, new systems, new processes, and entirely new paradigms for translating fundamental raw materials into finished products. In many cases, advanced manufacturing promises entirely new classes and families of products having previously unattainable properties and functionalities.

NSF has enjoyed long supported basic research investments in the sciences and engineering that have made dramatic impact on advanced manufacturing. Investment in basic research in advanced manufacturing exists through core programs primarily in three Directorates, namely Engineering (ENG), Computer and Information Science and Engineering (CISE), and Mathematics and Physical Sciences (MPS). For example, since 1987 NSF has had a division dedicated to supporting fundamental efforts within the design and manufacturing research community. Early research investments made by NSF have led to the creation of wholly new manufacturing processes including additive manufacturing (solid freeform processing) and tissue engineering Today, the Division of Civil, Mechanical and Manufacturing Innovation (CMMI) in ENG has an entire advanced manufacturing cluster, which supports manufacturing enterprise systems, operations research, manufacturing machines and equipment, materials processing and manufacturing, and scalable nanomanufacturing. Further, numerous cross-cutting programs have substantial investments in advanced manufacturing research, education, and industrial partnerships. Notably, the Grant Opportunities for Academic Liaison with Industry (GOALI) supports individual researchers from the core programs to collaborate directly with industry to ensure relevance, provide graduate and undergraduate students access to project based learning environments, and more easily translate research findings to practical use.

Additionally, NSF supports advanced manufacturing through several center-scale activities that provide support to activities that are more focused, larger scale, and greatly integrative in nature. For example, the Engineering Research Centers (ERC) program has a rich history of supporting frontier research aimed at solving systems level challenges in a holistic collaborative manner. Presently, the ERC program supports several centers that possess an advanced manufacturing focus, ranging from advanced particulate manufacturing techniques relevant to pharmaceutical industry to more broadly applicable computational tools to enable scalable nanomanufacturing. For example, the Structure Organic Particulate Systems (CSOPS) ERC at Rutgers, focuses on improving the effectiveness of the manufacturing of pharmaceuticals. Working with pharmaceutical industry leaders the CSOPS develops and integrates technologies for continuous manufacturing of tablets and capsules. This transformational approach moves the industry from costly batch processing towards affordable and higher quality continuous manufacturing techniques. Working with the ERC, industry has been able to demonstrate the capacity to effectively mitigate the three manufacturing challenges associated with batch processing: segregation, agglomeration, and compact quality. Recently the ERC and its industrial partners accelerated the commercialization of continuous processing technology. In a public-private partnership, NSF and industry provided funds to build experimental production lines. This

approach linked pharmaceutical companies (who usually compete with each other) in strategic partnership to advance this manufacturing technology which may become an industry standard.

All ERCs create a culture in academe that joins research, education, and innovation that builds upon partnerships with industry to strengthen the innovative capacity of the U.S. in a global context. NSF leverages funds from industry to support graduate students performing industrially relevant research in team environments with systems level approaches. Surveys of industrial partners indicate that ERCs produce engineering graduates who are creative and innovative practitioners, more capable of leading teams to advance technology in established firms or leading new firms. Through innovative education of talented graduate and undergraduate students, ERCs are providing our nation the next generation of scientific and engineering leaders.

Industry/University Cooperative Research Centers (I/UCRCs) have had tremendous impact on the advanced manufacutirng sector over the past two decades. These truly collaborative centers integrate industry, academia, and government laboratories to address use-inspired industrially relevant fundamental research questions, promote industrial collaboration in research and education integration, and enable direct transfer of innovative concepts, research results, and technology to U.S. industry. With industrial and other support totaling 10 to 15 times the NSF investment, I/UCRCs are a premier example of "leveraged" funding. Recent analysis of the centers indicates that there are roughly 700 industry partners; 100 member universities; state governments, and national laboratories that participate in one or more of the 59 centers. Of the current 59 centers, 17 directly contribute to advanced manufacturing research. Examples include the Center for Particulates and Surfactants at Columbia University, the Center for Laser and Plasma in Advanced Manufacturing at the University of Virginia and Southern Methodist University, the Center for Precision Forming at the Ohio State University and the Center for Sensors and Actuators at UC-Berkeley.

Through investments made over the past decade, the National Nanotechnology Initiative (NNI) has supported fundamental research projects that have produced countless dramatic discoveries and enabled wholly new approaches to sensors, electronics, and advanced materials. Yet, to realize the benefit of these discoveries, new scalable and sustainable manufacturing processes and techniques must be advanced since current practices and manufacturing technology may be inadequate. Consequently, NSF has supported nanomanufacturing research, facilities, and educational opportunities through a portfolio of centers, targeted solicitations, and a dedicated core program. For example, The Foundation supports NSECs (Nanoscale Science and Engineering Centers), that focus on manufacturing at the nanoscale. These centers have strong partnerships with industry and national laboratories. These centers are focused on solutions to unique scaling challenges that must be addressed in order to realize the promise of nanotechnology discoveries. NSF also supports the National Nanomanufacturing Network (NNN), which includes the NSF NSECs and non-NSF centers in collaboration with the Department of Defense (DoD), National Institute of Standards and Technology (NIST), and industry partners in an alliance to advance nanomanufacturing capabilities by providing access to shared state of the research instrumentation and analysis equipment. These facilities are used widely by the nanoscale science and engineering research community and have enabled rapid advances in sensors, energy storage, computer memory, and nanoelectronics. More recently NSF has participated in the NNI Signature Initiative on Scalable Nanomanufacturing, making

awards to support interdisciplinary research that accelerates nanotechnology breakthroughs towards scalable commercially viable manufacturing processes.

The NSF Small Business Innovation Research and Small Business Technology Transfer programs catalyze the development of small businesses, which are integral to new jobs and the economy. These programs have helped small firms successfully develop cutting-edge technologies and products and provided support to fledgling small businesses that form the core of the nation's manufacturing base. Across the government, SBIR programs are now the largest single source of patents in the United States. Within NSF, over 30% of the SBIR programs are focused on manufacturing topics. As the birthplace of SBIR, NSF takes special satisfaction in the program's expansion and positive impacts.

Micro-electronics pioneer Carver Mead has stated that a key enabler of the explosive growth of the microelectronics industry was the hiring of students who carried knowledge of the automated chip design techniques they learned in university labs into the industry. Similarly, a unifying feature of our plans for manufacturing education is the tight coupling of students to the existing manufacturing infrastructure through established interfaces and the development of novel software and networked infrastructure. Many recent studies and analysis on advanced manufacturing have specifically noted the need for highly educated and skilled workers at the community college and undergraduate level.. With an emphasis on two-year colleges, the Advanced Technological Education (ATE) program focuses on the education of technicians for the high-technology fields that drive our nation's economy. The program involves partnerships between academic institutions and employers to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. The ATE program supports curriculum development; professional development of college faculty and secondary school teachers; career pathways to two-year colleges from secondary schools and from two-year colleges to four-year institutions; and other activities. Another goal is articulation between two-year and four-year programs for K-12 prospective teachers that focus on technological education tightly coupled to industrially relevant needs. Presently the ATE program supports 9 centers that specifically address advanced manufacturing technologies and the specific needs in areas ranging from high-performance welding to rapid prototyping and additive manufacturing. Many centers have national impact beyond their communities. For example the National Center for Manufacturing Education (NCME) located at Sinclair Community College in Dayton, OH serves manufacturing and engineering technology educators with high-quality resources in emerging technologies and innovative classroom strategies via the Manufacturing and Engineering Technology Clearinghouse (METEC). This searchable database of materials provides quick and facile access to best practices in manufacturing education.

NSF's Proposed FY2013 Investments in Basic Research and Education Relating to Advanced Manufacturing

NSF's core scientific and engineering programs have produced many fundamental advances that have enabled and continue to enable breakthrough manufacturing technologies, many implemented worldwide. Core research programs and special initiatives achieve similar results

by bringing research communities together to address critical manufacturing needs that cross disciplines. NSF's educational programs enable faculty to develop the associated curricula and laboratories needed to prepare undergraduate and community college students in the new technologies needed by manufacturing companies, and NSF innovation programs transition these competitive new technologies to the marketplace.

Today NSF is developing a fully integrated manufacturing research and educational infrastructure into a coordinated program to address critical needs. One major issue we face is the near simultaneous availability of the most advanced manufacturing technologies throughout the world. Through our investments in basic research, we explore possibilities for increasing competitiveness by simplifying, streamlining, speeding, and vastly increasing the access of US citizens to manufacturing resources. Such access builds on the model of web-based commerce, leverages the Internet backbone, and takes advantage of our entrepreneurial culture that admires risk-taking and doesn't dishonor the failures that are the normal prerequisites of success. Our thesis is that this culture may be our true major global competitive advantage.

In FY2013, NSF will expand existing programs pertaining to advanced manufacturing research and education, and initiate some new programs and collaborations focusing on this area. The NSF's **Materials, Manufacturing, and Smart Systems (CEMMSS)** portfolio will spur marketplace innovation, leading to high technology jobs and industrial growth in the United States. This path-breaking effort accelerates the convergence of frontier research in materials, cyber-enabled systems, and manufacturing science. **Designing Materials to Revolutionize and Engineer our Future (DMREF)** will synergistically utilize cyber-enabled modeling, data, and experimental approaches to accelerate materials discovery and development, allowing the Nation to deploy advanced materials systems twice as fast as possible today at a fraction of the cost. This portfolio also will include research to advance sensor- and model-based smart manufacturing, advanced robotics and materials, and nano-manufacturing. Research on **Cyber Physical Systems (CPS)** will transform static manufacturing systems into adaptive, "smart" systems that can sense and adapt to environmental change. Likewise, the multi-agency **National Robotics Initiative (NRI)** will help develop robots that work beside, interact cooperatively with, or assist people in performing a variety of tasks.

NSF's contribution to the nanomanufacturing program component area of **National Nanotechnology Initiative (NNI)** will support new concepts for high-rate synthesis and sustainable processing of nanostructures, nanostructured catalysts, nanobiotechnology methods, fabrication methods for devices, and their assembly into scalable nanosystems and then into larger scale applications of importance to industry. Likewise, NSF's **BioEconomy** portfolio will demonstrate the Agency's commitment to investing in bio- and bio-inspired manufacturing research that will catalyze innovations in energy conversion technologies, biofuels, bio-based value-added chemicals and healthcare.

NSF will continue to encourage industry–university collaboration in support of advanced manufacturing. The Industry/University Cooperative Research Centers (I/UCRC) program, active in both ENG and CISE, is building innovative capacity in advanced manufacturing through its centers' long-term partnerships between universities and key industry sectors. The

Engineering Research Centers (ERC) program emphasizes systems-level approaches to providing next-generation manufacturing technology.

NSF will build upon longstanding relationships with DoD, DoE, DoC, EPA and NASA manufacturing programs through the NSTC Interagency Working Group on Advanced Manufacturing and other activities to pursue extensive partnering in advanced manufacturing. NSF will also participate in the Advanced Manufacturing National Program Office, which will be closely linked to the NSTC working group.

NSF STEM education programs are critical to the future of manufacturing in the U.S. The portfolio of research and education programs at NSF, such as the Engineering Research Centers and STEM education programs, will support these advanced manufacturing initiatives. The large-scale centers programs are necessary to bring synergy to the technical advances made in academic research such that they are readily adopted by industry. The Advanced Technological Education (ATE) program focuses on education for high-technology fields that drive our nation's economy, with an emphasis on two-year colleges to produce well-qualified science and engineering technicians for existing and emerging advanced technological fields. Partnerships between academic institutions and employers support career pathways to two-year and four-year colleges and into the workplace.

And finally, NSF expects to be a core partner in the National Network for Manufacturing Innovation, which was proposed by the President on March 9, along with the National Institute of Standards and Technology, and the Departments of Defense, Energy, and Commerce. We will be a partner with these same agencies in the pilot institute for manufacturing innovation, which the President announced in the same speech. Our primary role, as in other advanced manufacturing activities is to support basic research and education leading directly to advancements in this area. We very much look forward to partnership with our sister agencies in this endeavor.

Summary

Mr. Chairman, first and foremost, NSF is all about support for *basic research and education* in science and engineering. Our contributions to advanced manufacturing are no different. We will continue to provide support primarily for those research considerations that will have long term impact, and for those educational programs which contribute directly to strengthening the scientific and engineering workforce capable of contributing to "*the new advanced manufacturing*". Both of these objectives are key to the future of advanced manufacturing in this country.

Thank you Mr. Chairman for this opportunity to highlight NSF's contributions to the nation's advanced manufacturing agenda. I will be pleased to answer any questions you may have.