Testimony of

Charles H. Romine
Acting Associate Director for Laboratory Programs

National Institute of Standards and Technology
United States Department of Commerce

Hearing Before the

United States Senate
Committee on Commerce, Science and Transportation
Subcommittee on Science and Space

"The National Nanotechnology Investment: Manufacturing, Commercialization, and Job Creation"

July 14, 2011

Introduction

Chairman Nelson, Ranking Member Boozman, and members of the Subcommittee, thank you for the opportunity to appear before you today to testify about the Department of Commerce's National Institute of Standards and Technology's (NIST) role in nanotechnology and nanomanufacturing.

The Administration has aggressively worked to promote the growth of basic and applied nanotechnology. In February 2011, the National Science and Technology Council (NSTC) released the National Nanotechnology Initiative (NNI) Strategic Plan. The goals of this plan are to advance a world-class nanotechnology research and development program, move nanotechnology discoveries from the laboratory into new products for commercial and public benefit, encourage more students and teachers to become involved in nanotechnology education, create a skilled workforce and the supporting infrastructure and tools to advance nanotechnology and to support the responsible development of nanotechnology.

NIST has a key role in this initiative, consistent with its mission to promote U.S. innovation and industrial competiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

Specifically, in the area of nanotechnology, NIST has a number of existing and planned programs that support the development, adoption, manufacture, commercialization, and use of nanotechnology-based innovations and products. Furthermore, the NIST efforts in the area of nanotechnology have been a key element of the NNI, of which NIST is one of 25 participating agencies. As the benefits of the NNI continue to accrue, the role of NIST and breadth of its innovation-related programs will become even more important in ensuring that the end results match the promise in terms of new jobs and revolutionary technologies that benefit the Nation's economy and the American people.

Providing Industry with the Measurements and Technology to Support Innovation

NIST is uniquely equipped to develop the improvements in measurements and standards that are essential for the adoption of advanced technologies needed by U.S. manufacturers to compete more effectively in the global technology-intensive products market. The nanotechnology-related research conducted in NIST's laboratories and user facilities develops measurements, standards, and data crucial to a wide range of industries and Federal agencies.

NIST has a history of serving the needs of manufacturing sectors. NIST's work with the semiconductor electronics industry provides one compelling example. The 2007 "Economic Impact of Measurement in the Semiconductor Industry" report estimated that the $12 billion spent on advancing measurement capabilities during the decade beginning in 1996 will have saved that sector more than $51 billion in scrap and rework costs by 2011—a net benefit of $39 billion[1].

[1] http://www.nist.gov/director/planning/upload/report07-2.pdf

One high-profile area of current support to this industry is in measurements of the nanoscale material graphene. Graphene, the subject of the 2010 Nobel Prize in Physics, is one of the most promising materials for the next generation of semiconductor devices needed to make electronic devices ever smaller and faster. Working closely with academic and industrial partners, NIST has recently completed the most advanced ultra-low temperature scanning probe microscope in the world, allowing an international team of researchers to measure key properties of graphene with unprecedented resolution. This unique instrument includes multiple components developed jointly with NIST that are now products being sold by U.S. companies.

Measurements and modeling by NIST researchers are helping electronics industry manufacturers to develop improved and new processes for the nanofabrication of electronics components like microprocessors and memory chips. For example, following on a semiconductor industry roadmap determination that copper interconnects would be needed to manufacture smaller and faster devices, NIST researchers identified critical technical barriers and developed a new predictive modeling tool. The model helped lower the cost of R&D and reduced the time to production, resulting in an estimated NIST benefit-to-cost ratio of 5.8 and a net benefit for industry of over $9 million, according to a NIST 2008 economic analysis [2].

NIST employs a number of tools to enable technology and knowledge transfer from NIST to promote U.S. competitiveness, including cooperative R&D agreements, facility use agreements, and intellectual property tools such as NIST inventions, patents, and licenses. NIST is home to a significant number of Associates and Guest Researchers, including summer undergraduate students and postdoctoral researchers, who develop technical expertise at NIST before continuing in their scientific careers.

NIST has a history of working with industry through public-private partnerships and other consortia. These groups help drive manufacturing research priorities and leverage investments. For example, NIST's partnership with the Nanoelectronics Research Initiative (NRI), a consortium that brings together the semiconductor electronics industry, government agencies, and universities, has leveraged a modest NIST investment ($2.75 million per year) by $5 million per year from industry partners and $15 million per year from states to support projects at 30 universities to work in 4 regional centers. The partnership has attracted $110 million over five years in state and private funding to support business development and commercialization. NIST/NRI interactions are currently supporting 111 graduate students and have produced 159 scientific publications as well as patented technologies (3 issued and 2 filed). NIST is also engaged with industry consortia in the areas of flexible electronics and neutron-based measurements for the manufacture of soft materials such as chemicals, petroleum products, and pharmaceuticals.

The President's 2012 budget request outlines research priorities at NIST that are specific to needs in nanomanufacturing. This includes developing the measurement knowledge and capabilities to enable cost-effective in-line measurement techniques for closed-loop process control, thereby overcoming a major obstacle to large-scale nanomanufacturing. In addition, NIST researchers are planning to develop and demonstrate measurement capabilities required to overcome barriers to the manufacture of cost-competitive third-generation solar technologies,

[2] http://www.nist.gov/director/planning/upload/report08-1.pdf

which incorporate molecular films, quantum dots, nanoscale crystals, and other nanoscale structures. As part of the Materials Genome Initiative announced recently by the President, NIST will work together with other agencies to develop the computational and design tools needed to accelerate materials development for industry.

Also in FY 2012, NIST will continue close and targeted interaction with other agencies in the three NNI Nanotechnology Signature Initiatives: Sustainable Nanomanufacturing, Nanotechnology for Solar Energy Collection and Conversion, and Nanoelectronics for 2020 and Beyond. In February 2011, NIST organized and hosted a workshop in support of the Sustainable Nanomanufacturing initiative, on the topic of carbon nanostructured materials. This event brought together stakeholders from industry, academia, and government to identify the technical challenges to the commercial development of high-performance, carbon-based nanomaterials, and discuss potential pathways to establishing a public-private consortium to address these challenges.

Providing the Scientific Basis to Support the Safe and Responsible Deployment of Nanotechnology

Nanotechnology standards foster greater industry and consumer confidence, resulting in accelerated deployment of new products. NIST staff members actively lead the development of international nanotechnology standards and guidelines conducted through international fora and coordinated with other agencies through the NSTC. Altogether these activities create favorable conditions for the responsible transfer of nanotechnologies into products for commercial and public benefit.

An understanding of the environmental, health and safety aspects of nanomaterials and nanotechnology-based products (NanoEHS) is critical for the responsible development and oversight of nanotechnology. NIST research in NanoEHS provides the underpinning science and measurement needed for a science-based approach to risk management. Policymakers and regulators can use the information to ensure that the U.S. is supporting innovation, encouraging new technologies, and not creating trade barriers.

NIST's NanoEHS activities provide information and data for research institutions, regulatory agencies, the public, and industry. NIST activities include the development of reference materials for widely produced nanomaterials used in a broad range of applications, including electronics, personal care products, and construction materials. Examples include the first gold nanoparticle standard reference material; providing technical support and help to lead development of documentary standards that enable consistent and reproducible measurements of nanomaterial properties; and developing instruments and transferable methods to measure key properties of nanomaterials as needed by industry and regulatory agencies to make sound, science-based risk assessments.

NIST's FY 12 request will increase NIST's ability to further develop validated measurement methods, tools, standards, and protocols that help to enhance understanding of the safety of nanomaterials and their mechanisms of interaction with the environment and humans with a

focus on nanomaterials of greatest concern based on such factors as production volume, widespread use in products, and the potential for hazard or likelihood of exposure.

NIST will continue to coordinate its NanoEHS program with other Federal agencies' activities through the nanotechnology subcommittee of the NSTC, using the 2011 *NNI Environmental, Health and Safety Research Strategy*[3] as a framing document.

Providing Industry and Academia Access to Advanced Nanofabrication Facilities

NIST's Center for Nanoscale Science and Technology (CNST), is the nation's only nanotechnology user facility established with a focus on commerce. An important goal of the NIST CNST is to reduce measurement barriers to innovation, by providing industry, academia, and other government agencies with access to world-class nanoscale measurement and fabrication methods and technology. NIST has undertaken a sustained effort to reach out to industrial researchers whose access to these resources will help accelerate nanotechnology transfer to the marketplace; the number of industry users has roughly doubled on an annual basis since FY 2008.

The NIST CNST mission is guided by an understanding that rapid commercial development of nanotechnology—in particular, the speed with which industry can bring a specific new nanotechnology from discovery to production—depends critically on the availability and efficacy of applicable metrology tools and processes at each stage of the transition. Developing these tools and processes will have an immediate and significant impact on the commercial viability of nanotechnologies in a diverse array of fields, such as electronics, computation, information storage, medical diagnostics and therapeutics, and national security and defense.

The Nanofabrication facility (NanoFab) at the NIST CNST is a world-class, 60,000 square foot shared resource for nanofabrication and measurement — with over 19,000 square feet of cleanroom laboratory space and over 90 major commercial measurement and processing tools. To meet specific needs of industry, the NIST NanoFab has created a rapid, easy process for users to obtain equitable access to the facility, whether or not they are doing proprietary research. Research at the NIST NanoFab can be done by individual users or alongside a technical expert from the NIST NanoFab staff, imparting flexibility to industry users depending on the nature of the research and individual competencies.

In the few years since its inception, the NIST CNST has become a major national resource for nanoscale science and the development of nanotechnology. Having now completed its initial ramp up in staff, equipment, facilities, and processes, the NIST CNST is continuing to expand on its strategic relationships and collaborations with industrial and academic partners.

In FY 2010 the NIST CNST hosted nearly 1,000 researchers from companies, government institutions, and universities from across 39 states and the District of Columbia; during the same period NIST NanoFab tool use increased by 90%. Corporate researchers ranged from a small company, needing the tools to turn an invention into a working prototype, to a large company,

[3] draft publicly available; awaiting final clearance.

using the NIST CNST resources to reduce the development cycle time of future supercomputer technologies.

The President's FY 2012 Budget Request includes $5.18 million for the recapitalization of the NIST CNST. This funding is needed to replace and update the equipment and instrumentation in the NIST CNST so that it can continue to meet the nanoscale measurement and fabrication needs of growing numbers of industry customers and other stakeholders.

Accelerating the development of transformational technologies

NIST external partnership programs provide a coordinated set of activities to meet manufacturing challenges. The Technology Innovation Program (TIP) funds small companies and joint ventures comprised of businesses, institutions of higher education and other organizations such as national laboratories or nonprofit research institutes to support high-risk transformational R&D. The 2010 TIP competition focused on manufacturing technologies, resulting in awards to small companies and joint ventures producing a range of nanotechnology-enabled products in areas including flexible liquid crystal displays, organic photovoltaics, and lithium-ion batteries.

In its FY 2012 budget request, the Administration proposed the creation of the Advanced Manufacturing Technology Consortia Program (AMTech) at NIST. AMTech was also included in the President's recent Advanced Manufacturing Partnership (AMP) initiative that is aimed at strengthening support for U.S. manufacturing. The AMTech program will address a critical need for early-stage technology development by providing incentives for the formation of, and providing resources to, industry-led consortia that will support precompetitive R&D, thereby enabling technology development and creating the infrastructure necessary for more efficient transfer of technology. AMTech builds on lessons learned from NIST's partnership with the NRI, which I mentioned previously. In addition, although similar to TIP in the pursuit of high-risk, high-reward research, the AMTech program brings together multiple players in the innovation cycle, under a single consortium, to accelerate the pace of innovation in a particular industry sector. This strategy has the potential to drive economic growth, enhance competitiveness and spur the creation of jobs in high-value sectors of the U.S. economy.

Finally, the nationwide network of Hollings Manufacturing Extension Partnership (MEP) centers helps small and medium manufacturers strengthen their competitive positions. The MEP system does this by accelerating the adoption of technological innovations, facilitating the adoption of environmentally sustainable business practices, providing training and assistance to increase exports, promoting renewable energy initiatives, fostering market diversification, and connecting domestic suppliers to manufacturers. All of these services are to assist manufacturers in successfully competing over the long term in today's complex global manufacturing environment.

Conclusion

In conclusion, there is a breadth of programmatic activities at NIST covering scientific discovery, measurement science, standards development, and technology transfer relating to nanomanufacturing. NIST programs span all stages of the innovation ecosystem that enable the development and implementation of advanced technologies. These programs will help U.S. industry become more efficient and competitive. NIST is uniquely positioned to provide the scientific underpinnings for these emerging technologies that will foster the transfer of new technologies into products for commercial and public benefit.

I thank the Subcommittee for allowing me to discuss NIST's nanomanufacturing activities and I welcome the opportunity to answer any questions you may have.

Dr. Charles (Chuck) H. Romine

Dr. Charles (Chuck) H. Romine serves as the Acting Associate Director for NIST Laboratory Programs. He is responsible for oversight and direction of NIST's six laboratory programs and is the principal deputy to the NIST Director. The position of Associate Director for Laboratory Programs was created in October 2010 as part of the first major realignment of NIST programs in 20 years.

NIST's six laboratories include the Physical Measurement Laboratory, Material Measurement Laboratory, Engineering Laboratory, Information Technology Laboratory, the Center for Nanoscale Science and Technology, and the NIST Center for Neutron Research. The NIST Laboratories collaborate with U.S. industry and universities to conduct measurement, standards, and technology research that advances the nation's R&D infrastructure. The overarching goal of the NIST laboratory programs is to accelerate U.S. innovation, which is a major driver of economic growth and job creation.

Prior to his appointment as the Acting Associate Director for Laboratory Programs, Romine served as the Senior Policy Advisor to the NIST Director and as the Associate Director for Program Implementation within the NIST Information Technology Laboratory. He joined NIST in 2009 after serving for five years in the White House Office of Science and Technology Policy as the Senior Policy Analyst responsible for providing expert technical and policy advice to the President's Science Advisor for all areas related to information technology.

Romine began his career in 1986 with the Department of Energy after receiving a Ph.D. in applied mathematics and a B.A. in mathematics, both from the University of Virginia. He spent 15 years conducting research at Oak Ridge National Laboratory on advanced algorithms for supercomputers and four years at the Department of Energy Office of Science as program manager for the Office of Advanced Scientific Computing Research.