Testimony of

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Introduction

Chairman Massie, Ranking Member Wilson and Members of the Subcommittee, thank you for the opportunity to testify today about the NIST Laboratories and the vital role they play in enabling innovation and competitiveness. I am Willie May, Associate Director for Laboratory Programs at the National Institute of Standards and Technology (NIST). NIST is one of our Nation's oldest Federal laboratories and our mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology in ways that enhance economic security and improve our quality of life. Enabling innovation and competitiveness has been an important part of our mission since we were founded as the National Bureau of Standards 112 years ago. In the spring of 1900, when Congress was considering the Act that created the National Bureau of Standards, the accompanying Committee report stated:

> *"…that no more essential aid could be given to manufacturing, commerce, the makers of scientific apparatus, the scientific work of the Government, of schools, colleges, and universities than by the establishment of the institution…"*

That statement is as true today as it was then. From our early electrical measurement research to today's quantum information science, NIST has long been a center for high-impact research meeting the needs of academia, industry, and government.

In today's global economy, the ability of the United States to remain competitive relies increasingly on our ability to develop, manufacture and commercialize innovative technologies. The amount of scientific components in products has increased dramatically. Just think about how much more complex an iPhone is compared to early cell phones, let alone those that hung on everyone's kitchen wall. The ability of America to be technologically innovative both drives and is driven by our ability to observe and to measure. If you cannot measure something, you will not be able to control it. And if you cannot control it, you will not be able to reliably manufacture it. NIST's unique role is to advance measurements and standards to drive innovation and commercialization, thus enabling American industry to remain globally competitive. The important role that NIST plays in supporting innovation and commerce has been recognized time and again with NIST playing central roles in multiple national priorities from manufacturing to cybersecurity. NIST's labs' technological expertise provides the capability to meet these challenges. In my testimony today, I will outline the role that the NIST plays in the areas of measurement science, standards, and technology, as well as some of the significant impacts produced over the past several years.

The NIST Laboratory Programs

Since 1901, NIST has maintained the national standards of measurement, a role that the U.S. Constitution assigns to the Federal government[1], and has been supplying the measurements and tools to help U.S. industry compete successfully. As a non-regulatory agency in the U.S. Department of Commerce, an experienced partner of industry, and the Federal research agency

[1] Article 1, Section 8, Paragraph 5 of the Constitution of the United States accords to the Congress the power to ". . . fix the Standard of Weights and Measures."

specifically focused on promoting U.S. economic competitiveness, NIST is well-positioned to accelerate and promote innovation and advanced technologies through its laboratory programs.

The NIST laboratory programs work at the frontiers of measurement science to ensure that the U.S. system of measurements is firmly grounded on sound scientific and technical principles. Today, the NIST Laboratories address increasingly complex measurement challenges, ranging from the very small (nanoscale devices) to the very large (vehicles and buildings), and from the physical (renewable energy sources) to the virtual (cybersecurity and cloud computing). As new technologies develop and evolve, NIST's measurement research and services remain central to innovation, productivity, trade, and public safety.

The NIST laboratory programs provide U.S. industry, academia, and other Federal agencies with:

- Scientific underpinnings for basic and derived measurement units in the international standards community, measurement and calibration services, and certified reference materials;

- Impartial expertise and leadership in basic and applied research to enable development of test methods and verified data to support the efficient commercialization and exchange of goods and services in industry and commerce;

- Support for the development of open, consensus-based standards and specifications that define technical and performance requirements for goods and services, with associated measurements and test methods for conformity; and

- Unique, cutting-edge user facilities that support innovation in materials science, nanotechnology discovery and fabrication, and other emerging technology areas through the NIST Center for Neutron Research, which provides world class neutron measurement capabilities to the U.S. research community, and the NIST Center for Nanoscale Science and Technology, which supports nanotechnology development from discovery to production.

The efforts of the NIST laboratories are focused on three primary mission areas:

- Driving innovation through measurement science
- Accelerating the adoption and deployment of advanced technology solutions
- Providing world-class, unique, cutting-edge research facilities

NIST carries out its mission with staff that includes some of the world's foremost experts in the measurement science field. In the last 15 years, researchers at NIST have been awarded 4 Nobel prizes in Physics, Kyoto Prize in Material Science (an international Nobel level prize for non-Nobel awarded categories), 2 National Medals of Science, a MacArthur "Genius" Award, over 100 other national scientific awards annually among other recognitions. Because of the caliber of expertise of the NIST research staff, more than 2,800 collaborating researchers come to NIST each year to work alongside our researchers and assist NIST in the delivery of our mission. We are proud of the work we do and continually strive to provide cutting edge research in

measurement science to industry.

Driving Innovation through Measurement Science

NIST creates the infrastructure necessary to measure the performance and quality of products and services. In close cooperation with industry, academia, and other Federal agencies, NIST continually advances measurement science, develops standard protocols and test methods, and evaluates and generates data. These critical tools, which the private sector cannot provide due to the high cost and unique skills needed, are the foundations for interoperability between products and systems, enabling global trade.

Industry relies on NIST for the physical measurements and standards needed to enable advanced manufacturing, to develop and test new materials, to enable innovation, and to ensure compliance with regulations. NIST measurement research facilitates the diffusion of precision metrology into industry in a number of ways. Frequently, NIST researchers will develop the next-generation of measurement techniques that are adopted by industry and integrated into commercially available devices, such as scanning probe microscopes, mass spectrometers, and other high precision instruments.

In addition, NIST provides measurement and calibration services via its Standard Reference Materials®, calibration services, and Standard Reference Data programs. Certified reference materials are made available to industry, academia, and throughout the world on a cost-recovery basis, to assure the accuracy of measurements made daily throughout the United States. The calibration services NIST provides help customers achieve the highest measurement quality and productivity. NIST Standard Reference Data are well-documented numeric data used in technical problem-solving, research, and development. Looking to the future, NIST is working to develop a suite of portable, highly-precise devices that will provide customers with "in place" precision measurements to keep pace with ever-accelerating product development cycles. These chip-scale devices will be capable of being directly integrated into equipment and products to provide continuous quality control and assurance, freeing customers from complex measurement traceability chains and lengthy calibration procedures.

Examples of NIST work in this space include:

- **Solving biological measurement problems --** NIST is ideally positioned to work with industry and Federal regulatory agencies to develop innovative solutions to biological measurement challenges that will enable more efficient manufacturing and quality assurance processes. Biotech drugs, currently dominated by protein therapeutics, are the fastest-growing class of pharmaceuticals, as well as one of the fastest-growing categories of health care-related spending. NIST is developing measurement methods, protocols, and standards for improved characterization of biologic drugs throughout the manufacturing process. For example, NIST researchers are creating mass spectral methods and reference data including peptide libraries to enable more accurate characterization of manufactured protein drugs, and to aid biopharmaceutical researchers in their development of new protein therapies. In support of and in collaboration with industry through the nSOFT consortium, NIST is also developing unprecedented capabilities in determining structure of protein therapeutics based on neutron scattering

techniques. This will allow the manufacturers to more accurately assess the quality and uniformity of the medicines produced in the manufacturing process to enable their acceptance. Other bioscience efforts at NIST are targeted at providing measurement science and standards to support new technologies, such as ultra-high throughput- DNA sequencing, and the development of standards to support improved genetics-based disease diagnostics and therapies. By partnering with other Federal agencies including the National Institutes of Health and the Food and Drug Administration, the bioscience research program at NIST supports the new tools, standards, and approaches needed to support science-based regulatory decision-making and to create a flourishing environment for innovation in industry.

- **Pushing the frontiers of quantum science --** Researchers at NIST are continually pushing the boundaries of advanced, cutting-edge metrologies that can be applied to problems of national significance in a broad spectrum of areas including advanced telecommunications, defense, electronics, energy, environment, health, lighting, manufacturing, microelectronics, radiation, remote sensing, space, and transportation. In one such area, quantum-based communication and measurement systems that use novel quantum states of light are being developed worldwide. However, the technologies used to generate, manipulate, and detect these states of light are inadequate for many emerging applications. NIST research in this field focuses on the development of single-photon technologies for quantum information science and technology. Key projects involve investigating the use of nonlinear fibers and nonlinear crystals as a source of correlated photon pairs or "squeezed light," and then manipulating the squeezed light in new ways to enhance precision measurements, as well as computing and communications based on quantum physics. In addition to creating these non-classical states of light, NIST builds detector systems that are the best in the world at operating at the single photon level. Major recent accomplishments by NIST researchers in this program include demonstrations of the highest system detection efficiency for single photons (greater than 95 percent at 1550 nanometers; world-record, long-distance quantum key distribution systems using superconducting nanowire single-photon detectors; and the first ever time-correlated single-photon counting with superconducting single- photon detectors.

Helping Manufacturers Succeed in the Global Economy

NIST customers span the full range of industries, from established—such as automotive, aerospace, microelectronics, and heavy equipment—to emerging, including nanotechnology and biomanufacturing, across the NIST laboratory programs. The NIST laboratory programs heavily leverage partnerships with major industry and other stakeholders to help guide and inform the development of research programs. Advanced manufacturing is an important component of the NIST laboratory programs, and is ideally positioned across a number of emerging areas of potential opportunity:

- Biomanufacturing — Working closely with industry, the FDA, and consensus standards organizations, NIST is able to provide a supporting measurement infrastructure needed to gain detailed understanding of biomanufacturing processes and to design superior methods that yield higher-quality protein therapeutic products. Next-generation sequencing technologies promise to yield new discoveries for rapid disease detection and

reveal potential pathways for the manufacture of biologically-based products including fuels and chemicals. NIST efforts to develop needed SRMs® and validated protocols will be critical to underpin the use of sequencing technologies.

- Nanomanufacturing — NIST will continue to help companies overcome technical barriers to cost-effective, high-volume manufacturing of materials, devices, and systems that exploit the exceptional properties exhibited at nanoscale levels. NIST efforts include measurements and standards to help companies and regulatory agencies address potential environmental, health, and safety risks of nanotechnology-based products.

- Advanced Materials Modeling and Simulation – NIST plays an important role in the interagency Materials Genome Initiative, which has the goal of significantly reducing the time from discovery to commercial deployment of new materials. Through considerable interactions with industry and academia, NIST is developing and deploying needed data infrastructure, including data assessment and validation as well as data standards, and modeling and simulation tools to support advanced material development in the U.S.

- Smart Manufacturing and Cyberphysical Systems – Exploiting advances in sensors, data analytics, modeling and simulation, smart manufacturing integrates these technologies to improve performance at all levels. NIST is developing measurements and standards for automated in-process quality monitoring and control for factory-level production systems. Ultimately these efforts aim to speed development, adoption, and integration of leading-edge intelligent technologies to advance U.S. manufacturing and construction performance and the quality and durability of its cyberphysical infrastructure, such as transportation systems, smart grid, two-way power networks, and remote medical monitoring, diagnostic, and treatment capabilities.

- Energy Efficiency and Sustainability – Several programs are in place to help prepare for future measurement and standards in the area of energy efficiency in manufacturing. The recently completed NIST Net Zero Energy Residential Test Facility will allow researchers to test various high-efficiency and alternative energy systems, materials, and designs. NIST is developing sustainability metrics for manufacturers through activities including methodologies for sustainable processes and resources and the integration infrastructure for sustainable manufacturing. The methodologies characterize unit manufacturing and assembly processes, including supplier capabilities, enabling industry-level manufacturing assessments to improve production efficiency.

Accelerating the adoption and deployment of advanced technology solutions

Technology is rapidly evolving to integrate new capabilities across the economy, including manufacturing processes, transportation systems, critical infrastructure, and healthcare. While these innovations will contribute to the U.S. economy and quality of life, they also present associated challenges in interoperability, security, and resiliency. NIST programs respond to these challenges through the development of standards, prototypes, and guidelines, established through engagement with government and industry users and stakeholders. NIST's expertise in

measurements and standards, and its experience supporting industry, accelerate the transition from world-class basic research to applied solutions. To support this transformation, NIST provides test-beds, testing and validation methodologies, support for certification, and support for the development of standards that are essential for the adoption and dissemination of new technologies into wide-spread use in areas such as smart grid, cybersecurity, cloud computing, cyber-physical systems, and smart manufacturing, to name a few.

Smart Grid: NIST's involvement in the smart grid is a prime example of how NIST combines its core research capability with extensive stakeholder engagement to drive technology adoption. The smart grid is a planned nation-wide network that uses information technology to deliver electricity efficiently, reliably, and securely. As outlined Section 1305 of the Energy Independence and Security Act of 2007 (Public Law 110-140), NIST has "primary responsibility to coordinate the development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems." NIST initiated the Smart Grid Interoperability Panel (SGIP) to support NIST in coordinating standards development for the smart grid. The SGIP is a public-private partnership that defines requirements for essential communication protocols and other common specifications and coordinates development of these standards by collaborating organizations, enabling NIST to solicit input and cooperation from private and public sector stakeholders in developing the smart grid standards framework.

Cybersecurity: NIST is a recognized world leader in cybersecurity, with a track record of accelerating the development and deployment of cybersecurity solutions and standards that are reliable, usable, interoperable, and secure, as well as the measurements and standards infrastructure for emerging cybersecurity applications. Some of NIST's recent accomplishments in this area include

- The National Cybersecurity Center of Excellence (NCCoE) -- In FY12, NIST established the NCCoE and completed several steps towards becoming operational, including the establishment of temporary laboratory and office facilities at the joint NIST and University of Maryland Institute for Bioscience and Biotechnology (IBBR). The Center identified initial use cases in the areas of Healthcare Technology and manufacturing and began establishing key partnerships with industry to advance the development of solutions in these areas. The NCCoE will encourage the rapid adoption of advanced security technology by private sector companies, by bringing together experts from industry, government and academia to identify and solve some of today's most pressing cybersecurity challenges.
- The National Strategy for Trusted Identities in Cyberspace (NSTIC) – NIST is playing the lead role in implementing the Administration's strategy by facilitating the creation of an Identity Ecosystem that gives participants access to secure credentials and increases the opportunities for trusted on-line transactions. As part of this effort on September 20, 2012, the NSTIC National Program Office at NIST awarded more than $9 million for five pilot projects in support of the Identity Ecosystem.

World class, unique, cutting-edge research facilities

Industry, academia, and other government agencies have access to unique NIST user facilities

that support innovation in materials science, nanotechnology, and other emerging technology areas. The NIST Center for Neutron Research (NCNR) provides world-class neutron measurement capabilities to the U.S. research community, and the NIST Center for Nanoscale Science and Technology (CNST) NanoFab facility supports nanotechnology developments from discovery to production. The customer-focused mission of both NCNR and CNST includes the safe and reliable operation of the facilities, as well as the development and application of entirely new and cutting-edge measurement and fabrication techniques.

NIST Center for Neutron Research (NCNR): The NCNR develops, delivers and maintains world-class neutron measurement capabilities and applies them to science and engineering problems of national interest. The NCNR is operated as a major national user facility with merit-based access made available to the entire U.S. scientific and technological community. In a typical year, more than 2,200 research participants, representing some 42 states, 32 government agencies, and 46 U.S. corporations, utilize the NCNR for neutron measurement studies. Between 1998 and 2007, these users contributed over 2,500 high-impact research papers to the open scientific literature.

Neutrons are powerful probes of the structure and dynamics of materials, and can be used to study a range of material behavior, ranging from molecules inserted into membranes simulating cell walls to protons migrating through fuel cells. The NCNR's neutron source provides the intense beams of neutrons required for these types of measurements. Neutron-based research covers a broad spectrum of disciplines, including engineering, biology, materials science, polymers, chemistry, and physics. Some highlights of the work at the NCNR include:

- Neutron-based tools developed at NIST are being utilized to probe the structure and behavior of new materials at the nanoscale, making it possible to improve process technologies and develop new materials applications ranging from light-weight advanced materials for the auto industry to novel nanocomposites for polymer-based solar cells to innovative materials and approaches for the efficient energy storage.

- Measurements using neutrons are probing internal stresses in materials such as pipelines, turbine blades, railroad rails, and shock absorbers in order to understand and improve the performance of products used in industry, transportation, and national defense.

- In studies of the structure and motions of very large biological molecules such as proteins, NIST is using neutrons to probe the bending and folding properties essential to protein function. The insights gained could lead to the development of new drug therapies, new anti-toxins, and improved vaccines.

NIST Center for Nanoscale Science and Technology (CNST): The CNST user facility was created to reduce barriers to innovation by providing industry, academia, and other government agencies with access to world-class nanoscale measurement and fabrication methods and technology. The unique CNST operating model is designed to support both the current and future needs of the national nanotechnology enterprise. The shared-use NanoFab facility provides convenient, rapid access to a comprehensive, state-of-the-art commercial tool set for nanoscale measurement and fabrication. Looking beyond the current state of the art, the CNST

NanoLab creates the next generation of nanoscale measurement instruments and methods, which are made available through to the scientific community through collaboration.

In the few years since its inception, the CNST has become a major national resource for nanoscale science and the development of nanotechnology. The number of research participants at the CNST is increasing rapidly, exceeding 1,600 in FY 2012 (the fifth full year of operation), and continues to grow. The research participants represent diverse communities, including over 350 institutions from 39 states and the District of Columbia. CNST projects resulted in 160 publications and patents in FY2012, and helped more than 120 companies meet their measurement and nanofabrication needs.

Within the CNST, the NanoFab facility is a world-class, 5,600 square meter (60,000 square foot) shared resource for nanofabrication and measurement – with more than 1,800 square meters (19,000 square feet) of cleanroom laboratory space and more than 85 major commercial measurement and processing tools. To meet specific needs of industry, the NIST NanoFab has created a quick and easy process for researchers to obtain equitable access to the equipment. Research at the NanoFab can be carried out by individual users or with the assistance of a technical expert from the NanoFab staff, imparting the flexibility needed to satisfy the widest range of needs, from expert academic researchers to small companies with an innovative new technology but limited expertise in nanofabrication. Within the next three years, the NanoFab will add a variety of new commercial tools, including those for automated, reproducible lithography; wet chemical processing; and nanoscale patterning and chemical analysis of metals and other hard materials.

Recent highlights of work in the CNST include:

- NIST research is helping uncover the nanoscale structural changes that occur inside an individual nanowire battery during charging and discharging, providing valuable information for improving the efficiency and performance of future rechargeable power sources being developed based on nanowire technology. Scientists at CNST NanoLab have fabricated complete, functional single-nanowire lithium ion batteries optimized for characterization in a transmission electron microscope.

- Access to the CNST NanoFab facility is accelerating important technology developments, including a new method to make precisely shaped holes in diamond, potentially leading to long-lasting micromachines. Research participants from industry are using the NanoFab to develop key chemical modifications needed to make nanoparticles that are 10 times more effective for use in a commercial medical diagnostic system, and to create a novel nanoscale measurement device to spur the development of fuel cell power sources.

Mr. Chairman, in conclusion, the NIST laboratories play a unique role in our Nation's research and development enterprise. NIST sits at the nexus of science and industry, conducting cutting-edge, world-class measurement science and developing standards that allow industry to innovate and compete in the global economy. Ensuring that our researchers have the facilities and resources necessary to keep advancing the critical measurements that will enable U.S. industry to develop the most advanced and best products and services is the top priority for NIST. Thank you for inviting me to testify today. I would be happy to answer any questions.

Dr. Willie E. May is the NIST Associate Director for 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 more than 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 current position, Dr. May served as Director of the Material Measurement Laboratory, which serves as the Nation's reference laboratory for measurements in the chemical, biological, and materials sciences through activities ranging from fundamental research in the composition, structure, and properties of industrial, biological and environmental materials and processes, to the development and dissemination of certified reference materials, critically evaluated data, and other measurement quality assurance programs.

Previously Dr. May led NIST's research and measurement service programs in chemistry-related areas for more than 20 years. His personal research activities were focused in the areas of trace organic analytical chemistry and physico-chemical properties of organic compounds.

Other National and International Responsibilities: Dr. May has several leadership responsibilities in addition to those at NIST. He is Vice President of the 18-person International Committee on Weights and Measures (CIPM), Chairs the CIPM Consultative Committee on Metrology in Chemistry's Organic Analysis Working Group; Co-Chair's the Joint Committee on Traceability in Laboratory Medicine's Working Group on Reference Materials and Reference Procedures; Chairs the Executive Board for the Hollings Marine Laboratory in Charleston, SC.; and on the Board of Visitors for the University of Maryland College Park's College of Computer, Mathematical, and Natural Sciences.

Honors and Awards: Department of Commerce Bronze Medal Award, 1981; National Bureau of Standards (NBS) Equal Employment Opportunity (EEO) Award, 1982; Department of Commerce Silver Medal Award, 1985; Arthur Flemming Award for Outstanding Federal Service, 1986; NOBCChE Percy Julian Award for Outstanding Research in Organic Analytical Chemistry and Presidential Rank Award of Meritorious Federal Executive, 1992; Department of Commerce Gold Medal, 1992; American Chemical Society Distinguished Service in the Advancement of Analytical Chemistry Award, 2001; Keynote Speaker for the 2002 Winter Commencement Ceremonies, University of Maryland, College of Life Sciences; Council for Chemical Research Diversity Award, the NOBCChE Henry Hill Award for exemplary work and leadership in the field of chemistry, Science Spectrum Magazine Emerald Award in 2005, the 2007 Alumnus of the Year Award from the College of Chemical and Life Sciences at the University of Maryland, member of first class of inductees into the Knoxville College Alumni Hall of Fame in 2010 and Fellow of the American Chemical Society in 2011; Honorary Doctor of Science and Speaker at Graduate School of Arts and Sciences Commencement Exercises, Wake Forest University in 2012.