NIST Three Year Programmatic Plan 2015–2017

1 Introduction

The National Institute of Standards and Technology (NIST) promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in a range of strategic areas critical to the nation's economy. The America COMPETES Act (Pub. L. 110-69, 121 Stat. 572) outlines major roles for NIST in promoting national competitiveness and innovation, and also calls for NIST to submit a three-year programmatic plan concurrent with the submission of the President's budget request to Congress. This document summarizes the focus of NIST programs for use in planning and prioritizing investments over the three-year period, 2015 through 2017. NIST will continue to refine this plan as it works with the Administration to address national priorities.

This Plan, first, describes NIST's mission and goals as well as an overview of its major structural areas. Second, this Plan outlines the strategic framework upon which NIST defines its priorities: relevancy to national priorities and research and technical capacity optimization.

2 NIST Overview and Programmatic Objectives

Since 1901, NIST (known as the National Bureau of Standards until 1988) has developed and maintained key standards for the Nation, a role that the U.S. Constitution assigns to the Federal government, and has been supplying the measurements and tools to help U.S. industry compete. As a non-regulatory agency in the U.S. Department of Commerce (DoC), an experienced partner of industry, and the Federal research agency specifically focused on promoting U.S. economic competitiveness, NIST is well-positioned to accelerate and promote innovation and advanced technologies through its laboratory programs and its Innovation and Industry Services Programs.

> **Mission**: To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve the quality of life.

NIST plays a key role in the Department of Commerce's 2014–2018 Strategic Plan. Specifically NIST is a lead agency in DOC's efforts towards its innovation goal to ***Foster a more innovative U.S. economy – one that is better at inventing, improving, and commercializing products and technologies that lead to higher productivity and competitiveness,*** and the programmatic objectives outlined in this document are directly linked to supporting that goal:

Accelerate growth of innovation-intensive economic sectors by building public and private capacity to invent, improve, and commercialize new products and services. In order for innovative products to successfully enter and compete in the marketplace, a robust scientific and technological infrastructure is

required. Fundamental research at the forefront of science provides the seeds for the development of new products and services. Policies that accelerate the rate of transfer of technologies from lab to market bolster the return on government investment in research and development. Agreed upon ways to measure the performance and quality of new products against more established technologies provide the foundations of product interoperability and allow them to compete in the international marketplace. NIST provides leadership and coordination for technology transfer activities across federal agencies and laboratories. These activities include strategies to improve streamline the processes used to transfer technology to the marketplace and improvements in the way technology transfer impacts are measured.

NIST is the federal government agency responsible for providing the measurement science, tools, and standards critical to the growth of high-value, innovative economic sectors. 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 to the very large and from the physical to the virtual. 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 industry, academia, and other federal agencies with:

- Scientific underpinnings for basic and derived measurement units, thermodynamic, kinetic and materials property data, international standards , 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;
- Expertise and support for the development of 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 and the NIST Center for Nanoscale Science and Technology.

As described in the 2013–2015 Programmatic Plan, NIST plays a unique role advancing the federal government's technology transfer goals. NIST's responsibilities for tracking and measuring the impact of technology transfer activities from federal laboratories represents a distinctive policy role. NIST's Technology Partnership Office statutory coordination authority for inter-agency activities is recognized by the Administration's innovative Lab to Market Program.

NIST plays a leading role in the Administration's initiatives to ***Grow a more productive, agile, and high-value manufacturing sector through partnerships and collaborations that accelerate technology development and commercialization.***

The Advanced Manufacturing Technology Consortia program (AMTech), is a public-private partnership that will accelerate manufacturing research and early-stage technology development. This has the potential to drive economic growth, strengthen U.S. competitiveness, and spur creation of high-end technology jobs. AMTech provides cost-shared funding to industry-led consortia that will develop technologies to address major technical problems that will spur the adoption of advanced manufacturing capabilities in the United States.

To accomplish the objective to ***Increase the capacity of U.S. regional economies to accelerate the production of value-added goods and services by providing services to and investments in businesses and communities,*** NIST's Hollings Manufacturing Extension Partnership (MEP) provides technical and business assistance to small- and medium-sized manufacturers through a nationwide network of non-profit centers. As public/private partnerships, non-federal local technical experts in 60 centers nationwide help manufacturers understand, adopt, and apply new technologies and business practices, resulting in increased productivity, better performance, cost savings, waste reduction, and creation and retention of manufacturing jobs. MEP also acts as a strategic advisor to promote business growth and innovation and to connect manufacturers to public and private resources essential for expanding into new markets, developing efficient processes, and training an advanced workforce. A pilot program within MEP to support the reshoring of manufacturing activity and the reinvestment in U.S. industrial commons focuses on domestic supply chains. MEP will disseminate the results of this pilot program by developing new tools and services to accelerate technology deployment by small- and medium-sized manufacturers.

In addition to these strategic objectives, NIST programs contribute to DOC's innovation strategic goals by strengthening the digital economy and accelerating the development of industry-led skills strategies. NIST also has programs that support DOC's strategic goals in environment (***Ensure communities and businesses have the necessary information, products, and services to prepare for and prosper in a changing environment***), and data (***Improve government, business, and community decisions and knowledge by transforming Department data capabilities and supporting a data-enabled economy***).

3 The NIST Strategic Framework

To most effectively accomplish its mission, NIST must be capable, relevant, and effective. This means that NIST must be forward-looking in order to build and maintain world-leading scientific capacity in the technology areas that will shape future industries, while at the same time having the agility to build programs that apply NIST's technical capabilities to the Nation's most immediate needs. In addition, NIST must continue to strengthen and improve the internal processes necessary to accomplish its mission with the greatest efficiency and effectiveness possible.

NIST continually collects information on major national issues, shifting trends in science and technology, and the performance of key operational processes through a variety of mechanisms including meetings, workshops, industry visits, and objective peer review of its programs. This input is viewed in the context of the NIST mission to make decisions on where NIST needs to develop specific capabilities, how to best marshal existing resources to address current issues, and how to continually optimize the organization for improved performance.

Figure 1 NIST Strategic Framework

NIST is focusing investments on the priority areas described below. These areas, which have been emphasized by Congress, the Administration, and the President's Council of Advisors on Science and Technology, were selected based on alignment with NIST mission. To address these challenges, NIST is building technical and organizational capabilities that cut across these priorities.

3.1.1 Advanced Manufacturing

A top priority of the President is strengthening U.S. manufacturing. NIST, with one of the most comprehensive sets of programs supporting advanced manufacturing competitiveness, has been a key part of the Administration's efforts. NIST has a number of programs that advance the state of the art in manufacturing, with particular emphasis on government-industry-university partnerships and enabling technologies (such as robotics, additive manufacturing, nano- and bio-manufacturing, precision measurements, cyber-physical systems, and advanced materials development) that benefit multiple sectors. This includes: laboratory programs focusing on emerging technologies; the reinvigoration of the Manufacturing Extension Partnership, which supports accelerated technological innovation in the Nation's small and medium manufacturing base; and the Advanced Manufacturing National Program Office, which provides a leadership role in interagency coordination.

A number of major trends are shaping the future of manufacturing. Among them are the shift in global demand for manufactured goods toward emerging economies; the increase in the variety of products and the decrease in product cycles required to meet customer needs; the growing importance of value-added services in early-stage manufacturing and assembly and during in-service operation and maintenance; the greater intelligence and use of digital technologies in product design and manufacturing; and the competitive focus on increasing efficiency in all aspects of manufacturing from the use of assets and resources to building agility and robustness into production systems, including supply networks, at the local, regional, national, and/or global levels. To accommodate these trends, NIST is strengthening its technical portfolio and partnering capabilities in key areas.

Bioscience	There is enormous potential for U.S. leadership in the manufacture of products in emerging technology areas, which have grown out of the U.S. investment in the biosciences and nanotechnology. NIST will provide the measurement science, data, and tools that are needed for efficient manufacturing in these areas. NIST research in biomanufacturing will help create new manufacturing paradigms that use cells as factories for fuels, pharmaceuticals, and specialty chemicals.
Data analytics/ Big Data	Much of advanced manufacturing depends upon the ability to make at scale or integrate the use of new materials into existing manufacturing processes. To support this need NIST will continue to invest in strengthening its efforts to develop the standards and data needed to support advanced materials modeling and design.
Systems Engineering	The convergence of digital technologies with manufactured products, engineered systems of products, and associated services are enabling a new generation of smart manufacturing processes and equipment. As these processes have grown exponentially in complexity, new and revised standards are required to accompany dramatic improvements in systems engineering, integration, and testing. NIST is strengthening its efforts supporting the closer integration of robotics and humans in the manufacturing environment, and is developing a testbed to evaluate the automated in-process quality monitoring and control systems that are critical to the efficient operation of modern factories.

In-Place Precision Measurement	Lasers are an enabling technology for an enormous range of measurements in physical standards, chemistry, biological systems, space-based research, and many other areas. NIST is the world leader in the development and application of ultrastable lasers. However, the coherence (or stability) of lasers has not significantly increased over the past decade despite intense world-wide research efforts. NIST researchers are developing a research program to achieve laser frequency stability more than 100 times better than the world's best lasers today, and extend optical coherence times to more than 1,000 seconds. The resulting ultrastable lasers will represent a dramatic breakthrough in fundamental precision measurement technologies impacting a broad range of metrology and research applications, including new optical atomic clocks, quantum information systems, and gravity wave detection.
Collaboration and Partnership	NIST's new ***Advanced Manufacturing Technology Consortia (AMTech) program*** will provide financial assistance to leverage existing consortia or establish new industry-led consortia to develop road-maps of critical long-term industrial research needs as well as fund research at leading universities and government laboratories directed at meeting these needs. The ***National Network for Manufacturing Innovation (NNMI)*** is a proposed network of manufacturing innovation institutes that would bring together companies, university and community colleges, and government to co-invest in applied research and development of cutting-edge manufacturing technologies. NNMI is a one-time investment to create a sustainable space where industry and academia can work together to scale-up and de-risk new technologies, along with developing workforce skills for U.S. manufacturers. NIST plans to fully leverage the existing capabilities and assets of the nationwide network of MEP Centers—and to amplify MEP efforts—to provide technology transition and commercialization services needed by U.S. small manufacturers to foster their readiness to adopt and/or adapt advanced technologies into their manufacturing processes and products and enhance domestic supply chain competitiveness.

3.1.2 Cybersecurity

NIST has a primary role in promoting cybersecurity performance in both the government and private sectors. These programs include cybersecurity standards; enabling technologies to promote cybersecurity; developing a Framework to protect critical infrastructure; implementing the National Strategy for Trusted Identities in Cyberspace and the National Initiative for Cybersecurity Education; establishing a new public-private collaboration for accelerating the widespread adoption of integrated cybersecurity tools and technologies; and protecting government information technology (IT) systems under FISMA. The following are examples of efforts NIST is taking to strengthen its capabilities in this space.

Data analytics/Big Data	There is a growing realization in the IT industry that current cyber-security technologies are losing an arms race with those who seek to launch network-based attacks. The current state of the art in Network Intrusion Detection technologies, which detect specific signatures of malicious software, cannot keep pace with the rate of innovation in attack vectors. Such schemes are inherently reactionary, requiring the identification and reverse engineering of new attacks and the near constant update of attack-signatures in global security systems. Recent advances in Network Anomaly Detection (NAD) technologies may stop this arms race by shifting the focus from identifying specific attacks toward detecting significant deviations from models of normal network behavior. While there has been much promising academic research in NAD technologies, the technologies are not yet effective enough to use in modern production networks. A primary barrier to further NAD technology development and commercialization is the lack of realistic reference data and techniques for rigorous test and measurement. NIST is beginning a research program to develop methodologies to generate high-fidelity, purely synthetic reference data of network traces to approximate the diversity of real network traffic that can be instrumented with controlled instances of malicious traffic. The spatial scale, application diversity, technology diversity, and temporal range that must be modeled present a significant technical challenge.
Systems Engineering	The computing systems that enable modern life, from the Internet to those that control critical infrastructure, are growing in both scale and complexity. The inability to measure, predict, or control macroscopic behavior in complex information systems can jeopardize our nation's security and cost billions of dollars through high-profile system events such as cascading failure modes. NIST is applying its core competencies in applied and computational mathematics, measurement science, and systems engineering to characterize macro-scale structures and dynamics of large-scale interconnected systems and to understand behavior in complex information systems.
Collaboration and Partnership	***National Cybersecurity Center of Excellence—***In the face of the Nation's cybersecurity challenges, NIST, with the State of Maryland and Montgomery County, established the NCCoE in 2012. The NCCoE is collaborating with experts from industry, government, and academia to build standards-based reference designs to address common cybersecurity challenges. In 2013, the NCCoE launched its first "use case" to develop a platform that allows health care providers to securely collect, process, and exchange patient data. This first use case was quickly followed by four others focusing on challenges in critical infrastructure sectors including financial services and energy. In addition to sector-specific use cases, the NCCoE is working on "building block" solutions that can be applied across industry sectors. Active building blocks include work on hardware roots of trusted geolocation for cloud computing, attribute-based access control, mobile device security, and software asset management. The NCCOE has attracted 19 industry partners to provide hardware, software, and expertise to aid the Center's efforts in advancing the rapid adoption of secure technologies. ***Cybersecurity Framework—***After last year's signing of the Executive Order "Improving Critical Infrastructure Cybersecurity", NIST worked with hundreds of U.S. businesses across multiple industries; with academia, and with state and local governments to create a Cybersecurity Framework to reduce the cybersecurity risks that the nation faces from hackers, foreign countries, and our nation's enemies. This framework was created in a public-private partnership, involving over 3,000 individuals in workshops across the country, and will help ensure that our national infrastructure is resilient against cyber attacks, to protect privacy of users and consumers, and to share and exchange actionable cyber threat information.

3.1.3 Advanced Communications

Broadband communications networks have become as essential to today's economy as the electrical power grid was to the Industrial Revolution. To compete effectively in this global business environment, communities and companies will need high speed, reliable, and secure access to huge amounts of data, available anytime, anywhere. NIST's modeling, measurement science, and experience convening

stakeholders to develop common standards and frameworks will enable significant innovation in communications in both the commercial and public safety sectors.

Systems Engineering	With the clear need to address the Spectrum Crunch, NIST is planning to invest in a number of efforts that will both improve spectrum efficiency and shared spectrum use. Planned efforts include the development of test facilities that can replicate a variety of complex electromagnetic environments to better characterize the performance of systems, as well as efforts to develop protocols and measurements techniques to utilize radio technology diversity to improve efficient use of spectral resources. In addition NIST is planning to build the capabilities needed to enable multiple and different types of wireless devices to operate in the same frequency band without affecting the performance of other devices in that same band. Efforts in this space would include work in cognitive radios, high-fidelity waveform metrology, smart antennas, and improved timing and synchronization for communications systems.
Precision Measurement	***Microelectromechanical Systems—***One enabling technology of the mobile computing and advanced communications revolutions is microelectromechanical systems (MEMS), microscopic devices comprised of a central microprocessor and several microsensors. MEMS have many applications from air bags in automobiles to gyroscopes in smart phones. The high frequency response, along with low energy loss and small device volume, of some micro- and nanomechanical systems has impelled the use of MEMS and nanoelectromechanical systems (NEMS) as replacements for components in radio frequency (RF) electronics, including filters, switches, and oscillators. They are expected to play a critical role in areas including mobile communications, wireless networking, and commercial broadcasting. However, even the state of the art in motion metrology cannot measure these high-frequency, low-amplitude motions, motivating the development of new measurement methods to accelerate innovation and commercialization of MEMS and NEMS devices.
Collaboration and Partnership	***Center for Advanced Communications—***Together with the National Telecommunications and Information Administration, NIST is establishing a national Center for Advanced Communications in Boulder, Colorado. The center will leverage the critical mass of NIST and NTIA research and engineering capabilities concentrated in Boulder to form a unique national asset, and includes the infrastructure and collaborative environment needed to address a wide range of advanced communications challenges.

3.1.4 Health Care and Bioscience

NIST has a long history of contributions to health care through metrology and measurement services. NIST's impact is set to continue to grow through R&D investments that have the potential to foster biological innovations in health, national security, energy, and agriculture, particularly in platform technologies (e.g. technologies for the design of biological systems, understanding systems biology, and high throughput biology) and research at the interfaces of biology, physical sciences, and engineering.

Data analytics/Big Data	***Office for Data and Informatics—***Researchers and institutions in the materials, chemical, and biological sciences need to leverage the both large and information-rich data sets that are now common in many disciplines. Stakeholders are faced with challenges of handling, archiving, storage, and analysis of data to transform such data into products that can be reliably and broadly shared and used for sophisticated scientific endeavors. To address this trend, the NIST Materials Measurement Laboratory is establishing an Office of Data and Informatics, which will build, concentrate, integrate, and coordinate capabilities needed to meet data challenges, and leverage data-driven research opportunities, that relate to the chemical, materials, and biological science communities. ***Predictive Models for Complex Biological Systems—***Advanced medical diagnostics and treatments, and manufacturing applications involving cells, require better understanding than currently exists of how intracellular networks operate, so that therapies can be deployed safely and biological manufacturing systems can be engineered efficiently. While methods to acquire more biological data faster have been advancing, little has advanced in how to use these data to understand the fundamental organizing principles of biological responses. Nascent efforts by NIST and others indicate that biological systems may be understood through general theoretical frameworks that explain many common phenomena. Advancing this fundamental understanding requires building capabilities in computation, statistics, and theoretical modeling for biological systems.
Bioscience	***Precision medicine—***Having the ability for precise and individualized diagnosis and treatment of disease has the potential to revolutionize the practice of medicine and the delivery of healthcare with more accurate and precise diagnostics having an important role in driving down healthcare costs. NIST has identified the need to strengthen capabilities that will enable the delivery of measurement tools that will support multiplex analysis of proteins, genetic material, and metabolites. ***Enhanced Imaging—***Advances in bioimaging technology have revolutionized medicine. To support continued innovations in this field, both in the manufacture and use of medical imaging technologies, NIST has identified the need to develop more comprehensive measurement tools and standards relative to both x-ray and magnetic-based imaging platforms.
Collaboration and Partnership	The ***nSoft Consortium***, a NIST-led consortium of industrial, government, and academic members, operates in a new model of access for industrial research programs to federally funded research facilities such as the NIST Center for Neutron Research (NCNR). The NCNR's cold neutron source is well-suited to probe the structure and dynamics of biological samples. Since neutrons are sensitive to the positions of the light elements that are of central importance to all biological systems, neutron scattering can provide unique information on the structure and function of biological macromolecules. This model is being applied to collaboratively develop neutron-based measurement solutions for manufacturers of soft materials. Through engagement of its members in the planning, development, and execution of research programs, nSoft is providing (1) predictable and timely access to neutron facilities, (2) research and development programs focused on high impact issues in soft materials manufacturing, and (3) increased scientific capacity through training programs and collaborative activities. ***The Institute for Bioscience and Biotechnology Research*** (IBBR), a collaboration among the University of Maryland College Park (UMCP), the University of Maryland Baltimore (UMB) and NIST, focuses on fundamental measurement problems in structural biology, biophysics, bio-engineering and computational biology to support innovation in biotechnology with an emphasis on advanced therapeutics.

3.1.5 Forensic Science

NIST provides measurement science to further the forensic science used to discover, expose, and explain physical evidence that enables the justice system to hold criminals accountable, exonerate the innocent, and protect the public from further harm. NIST supports the forensic science community through the research and development of traceable standard materials, reference data, and calibration systems.

The NIST laboratories have partnerships with professional associations, standards developing organizations, government, industry, and academia, which enable NIST to strengthen and expand efforts to advance measurement quality for forensic science. The NIST laboratories have complementary expertise that will further enable research to characterize and improve the accuracy and efficacy of many forensic approaches, aiding practitioners by providing tools for crime scene investigation, laboratory analysis, and court room use of this evidence.

Precision Measurement	NIST has an established core capability in a number of forensic science areas. For example, NIST research in human identity and forensic DNA testing, developed in collaboration with the National Institute of Justice (NIJ/DOJ), has resulted in the development of standard reference materials, new testing methods, inter-laboratory validations, and the creation of training materials. The successful development of this core competency in DNA testing is a product of technical expertise along with a commitment to and engagement with the forensic community to develop relevant products. NIST will continue to establish and expand the science base to support the development of new measurement methods standards and quality assurance tools needed by the forensics community. The NIST laboratories will perform research to characterize and improve the accuracy and efficacy of many forensic approaches, aiding practitioners by providing tools for crime scene investigation, laboratory analysis, and court room use of this evidence while also enabling NIST laboratories to innovate completely new approaches to forensic science disciplines.
Collaboration and Partnership	NIST is partnering with the Department of Justice to establish a National Commission on Forensic Science to strengthen and enhance the practice of forensic science. The Commission will be composed of approximately 30 members, bringing together forensic science service practitioners, academic researchers, prosecutors, defense attorneys, judges, and other relevant stakeholders to develop policy recommendations for the Attorney General. The commission will consider guidance on practices for federal, state and local forensic science laboratories developed by NIST-administered groups of forensic science practitioners and academic researchers.

3.1.6 Climate Change and Clean Energy

In order to help address major environmental issues facing the Nation, NIST develops measurement capabilities that are fundamental to measuring environmental change, untangling natural variation from human-induced causes, predicting the consequences, and establishing a technical basis for effective incentives and regulatory structures. In addition, advanced measurements often open paths to innovation, enabling the development of clean technologies that conserve resources, minimize environmental footprints, and generate new business and export opportunities. In addition, NIST works on disaster-resilience standards to boost the resilience of buildings and infrastructure to the impacts of climate change.

Bioscience	Because there is presently no comprehensive source of reliable biofuels property data, NIST is developing methods for the determination of biofuel composition and properties and disseminating related measurements, models, reference materials, and property databases. NIST's work supports the wide-spread adoption of biofuels and future alternative fuels, including new formulations for defense and aviation applications.

Systems Engineering	Buildings are complex systems with many interacting elements – for example, the temperature inside a building is affected not just by the HVAC system, but also the building envelope, sunlight coming through windows, and appliance use and efficiency. Due to the complexities of these interactions, improvements in the energy performance building materials, components, and systems don't always produce the expected reductions in overall energy use. The interactions between the components and systems that comprise a building must be considered in concert to enable maximum energy efficiency. NIST is developing measurement science that enables architects and developers to design buildings that produce as much energy as they consume and to use more durable materials. NIST will leverage its expertise in the areas of energy, service life prediction, life-cycle assessment, and indoor air quality to deliver test methods/performance metrics that assist the marketplace in capturing the value of green building technologies while maintaining pleasant environments.
Collaboration and Partnership	To protect critical infrastructure and public resources, NIST will lead the development of a Disaster Resilience Framework for building and infrastructure resilience. The framework will apply to many types of hazards (e.g., tornadoes in the Midwest and earthquakes on the West Coast). A Disaster Resilience Standards Panel, convened by NIST, will further refine the framework and identify model resilience guidelines to put the framework into action. This national effort will require significant engagement with stakeholders and federal agencies, including NOAA, the Department of Homeland Security, the Federal Emergency Management Agency, the U.S. Geological Survey, the Department of Transportation, the Department of Housing and Urban Development, and the National Science Foundation.