# NIST THREE YEAR PROGRAMMATIC PLAN

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

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# 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 this three-year period. NIST will continue to refine this plan as it works with the Administration to address national priorities.

# 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, 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 QUALITY OF LIFE.**

The following goals will ensure NIST develops the technical capabilities and adaptability necessary to carry out its key role in the Nation's innovation ecosystem:

# GOALS:

## STRENGTHEN NIST'S LABORATORIES AND FACILITIES TO ENSURE U.S. LEADERSHIP IN MEASUREMENT SCIENCE.

The vitality of the NIST Laboratories is crucial to meeting the complex and demanding measurement and standards challenges associated with new technologies required to maintain U.S. economic and national security. NIST will continue to invest in high-performing facilities, equipment, infrastructure, and personnel.

## FORTIFY U.S. ADVANCED MANUFACTURING CAPABILITIES.

The Nation's long-term competitiveness relies on its global leadership in advanced manufacturing capabilities. NIST will develop and deploy unique tools to support U.S. advanced manufacturing through its laboratory research programs, the Hollings Manufacturing Extension Partnership and the National Network for Manufacturing Innovation.

## MAXIMIZE NIST'S IMPACT THROUGH EFFECTIVE COLLABORATION.

NIST has the greatest impact when the knowledge and technology generated by its research is transferred to industry, universities, standards organizations, and other government agencies. NIST will continue to pursue partnership opportunities to better deliver measurement solutions, provide access to unique measurement capabilities, participate in standards-setting organizations, convene consortia, license intellectual property, and attract and train high-quality research associates.

## DEVELOP WORLD CLASS OPERATIONS AND SUPPORT SERVICES.

NIST's activities are most efficient and effective when supported by exceptional business practices, strategic planning, safety culture, and operational offices. NIST will improve its practices to enhance the business of NIST by accelerating the delivery of services critical to operate its mission-focused programs at the speed of industry needs.

NIST's mission to promote innovation and industry competitiveness is best served when we support activities throughout the research and development pipeline, from the most basic science to the deployment of advanced technologies. NIST programs are designed to span this pipeline, enabling organizational excellence for institutions from non-profits, universities, and other federal agencies to manufacturers, supporting advanced manufacturing by facilitating pre-competitive and applied research as well as technology deployment, and performing world-class metrology and technology research and services.



## 2.1 THE NIST LABORATORIES

The NIST laboratory programs work to advance 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, evolve and become more complex, NIST's measurement research and services remain central to innovation, productivity, trade, and public safety.

The NIST laboratory programs provide industry, other federal agencies, and academia with:

- Scientific underpinnings for basic and derived measurement units, internationally accepted standards, measurement and calibration services, and certified reference materials;
- Impartial expertise and leadership in basic and applied research that enables development of test methods and verified data to support efficient commercialization and commerce;
- Expertise and support for consensus-based standards development, with associated test methods for conformity; and
- Unique, cutting-edge user facilities that support innovation in emerging technology areas.

SPOTLIGHT ON: BIOLOGICAL MEASUREMENTS

NIST's broad measurement expertise has allowed it to make significant contributions to biology and healthcare. In the area of biomedical imaging NIST in partnership with clinical stakeholders is developing measurement techniques that allow improved quantification of results, enhanced repeatability, and improved safety. Further NIST research efforts are providing needed measurement capabilities to the growing biotherapeutic and synthetic biology industries where NIST measurement capabilities and standard reference materials are overcoming significant industrial and regulatory challenges including the characterization and approval of protein drugs, the validation of whole-genome sequencing, and the authentication and verification of cell lines used in both research and biomanufacturing.

Looking towards the future, NIST is investing in capabilities and partnerships to ensure these industries continue to have the measurement infrastructure necessary for competitiveness and quality. For example, NIST aims to develop measurement technology for predictability in engineered biological systems by applying leading NIST capabilities in photonic and electromagnetic sensors and new biological measurement technologies to quantitatively measure biological systems, and by developing databases and measurement methodologies to systematically characterize engineered biological systems.

## *Driving innovation through measurement*

NIST creates the infrastructure necessary to measure the performance and quality of products and services. In close cooperation with industry, other federal agencies, and academia, NIST continually advances measurement science, develops standard protocols and test methods, and evaluates and generates data. These 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 increasingly demanding physical measurements and standards needed to enable advanced manufacturing, to develop and test new materials, to enable innovation, and to ensure compliance with regulations. In addition, NIST provides measurement and calibration products and services via its Standard Reference Materials®, calibration services, and Standard Reference Data programs. These products and services assure the accuracy of measurements made daily throughout the United States.

SPOTLIGHT ON: SERVICE DELIVERY

NIST continuously looks for ways to improve the delivery of its core products and services—from calibrations and SRD to access to its user facilities. NIST remains relevant to today's industry norms to maximize access and use of NIST's products, services, and capabilities essential to U.S. competitiveness. To this end, NIST will be modernizing web access to these core services over the coming years. Examples of efforts in this area include:

- Improving the web interfaces for its Standard Reference Data to increase usability and accessibility of those products.
- Creating a calibration customer electronic portal that can process requests for calibrations and quotations and provide access to reports and history.
- Developing infrastructure for remote access to the capabilities of the Center for Nanoscale Science and Technology's NanoFab.

These changes in how we interact with our customers via the web are one component of a broader strategy to enhance how NIST delivers core services. Through the NIST-on-a-Chip program, NIST is pursuing groundbreaking research to develop chip-scale standards and sensors for use in the field, reducing the time and expense associated with the shipping of equipment required for remote calibrations. Finally, NIST continues to explore options to enhance training to meet the needs of advanced technology metrology in the laboratory and factory floor.

## *Accelerating the adoption and deployment of advanced technology solutions*

Technology is rapidly evolving to integrate new capabilities across the economy, including in manufacturing processes, transportation systems, critical infrastructure, and healthcare. While these innovations will contribute to the U.S. economy and quality of life, they have associated challenges in interoperability, security, and resiliency. The NIST Laboratory programs respond to these challenges by engaging with government and industry stakeholders to develop the standards, prototypes, and guidelines essential for technology adoption and dissemination. In addition, NIST provides test-beds, testing and validation methodologies, and support for certification to support technology deployment.

SPOTLIGHT ON: CPS

Cyber-physical systems (CPS) are co-engineered networks of physical and information technology components interacting with their environment in real time to optimize performance, safety, security, resilience, and reliability. Current CPS applications are emerging from diverse commercial applications, the isolation of which hampers interoperability and therefor global growth; a recent report estimated that 40% of potential economic impact of CPS technologies relies on system interoperability. Industrial efforts in CPS have been growing in response to an expanding market opportunity. Cyber-physical systems research efforts take place today in the academic, commercial, and government sectors, but are typically mission-based and implementation-focused. NIST is partnering with industry, academia, and government through its Public Working Group and its SmartAmerica and Global City Teams Challenge to drive development of cross-domain CPS solutions.

## *World class, unique, cutting-edge research facilities*

Industry, academia, and other government agencies have access to unique NIST user facilities that support innovation in 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) supports the U.S. nanotechnology enterprise from discovery to production by providing access to world-class nanoscale measurement and fabrication methods and technology. The customer-focused missions of both NCNR and CNST include the development and application of entirely new measurement and fabrication techniques while ensuring safe and reliable facility operations.

SPOTLIGHT ON: FUELING INNOVATION

Neutrons have been enormously successful as a unique probe of the structure and dynamics of materials for researchers from many different backgrounds, including academia and industry. Neutrons can provide information that simply cannot be obtained using more conventional methods available in the researchers' own laboratories. Worldwide, the demand for access to neutron measurement capabilities far exceeds the supply, and the NIST Center for Neutron Research (NCNR) is the only U.S. facility with a focus on enhancing industrial competitiveness.

The NCNR uses a 20 MW research reactor as a neutron source. The reactor operates 24 hours a day, seven days a week for approximately 250 days of the year to support experiments by over 2,000 research participants annually. Delivery of the NCNR mission—to develop and provide advanced neutron measurement techniques and instrumentation for research—requires the research reactor to operate safely and reliably. The future operational status of the NCNR is threatened by increasing costs of fuel and maintenance and upgrades.

## 2.2 NIST INNOVATION AND INDUSTRY SERVICES (IIS)

In support of the Administration's emphasis on serving industry through outreach services, NIST provides two important externally-focused services: The Hollings Manufacturing Extension Partnership (MEP) and the Baldrige Performance Excellence Program (BPEP). NIST is also the home of the Advanced Manufacturing National Program Office, which coordinates the National Network for Manufacturing Innovation (NNMI).

NIST's MEP provides technical and business assistance to smaller manufacturers through partnerships between Federal and state governments and non-profit organizations in all 50 states and Puerto Rico. Field agents and programs help manufacturers understand, adopt, and apply new technologies and business practices, increasing productivity, performance, cost savings, reducing waste and creating and retaining manufacturing jobs. MEP also is 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.

NIST plays a coordinating role for the NNMI, serving the existing Institutes for Manufacturing Innovation (IMI) and future IMIs. In an IMI, industry, academia, and government partners leverage existing resources, collaborate, and co-invest to nurture manufacturing innovation and accelerate commercialization. In addition, NIST announced a competition seeking applications for new NNMI Institute awards. The Federal investment in the NNMI creates an effective manufacturing research infrastructure for U.S. industry and academia to solve industry-relevant problems. The NNMI works to maximize the integrated impact of the IMIs on U.S. manufacturing competitiveness. Further, the NIST Laboratories are deeply involved in the existing IMIs, providing technical input and opportunities for research collaboration.

BPEP manages the Malcolm Baldrige Quality Improvement Act of 1987 (Public Law 100-107), in cooperation with senior U.S. business, education, health care, government, and nonprofit leaders. To enable the further competitiveness and success of U.S. organizations, BPEP promotes broad use of the Baldrige Excellence Framework, the nation's standard for leadership and management practice. BPEP provides organizational assessments, executive development, and training to U.S. organizations in all sectors of the economy and supports a nationwide network of state, local, and regional Baldrige-based programs. Notably, BPEP administers the Malcolm Baldrige National Quality Award, which recognizes high-performing, role-model U.S. organizations. Through the award process, conferences, training, social media, and other outreach, BPEP helps disseminate their best practices to thousands of organizations each year.

With the America COMPETES Reauthorization Act of 2010, the Under Secretary of Commerce for Standards and Technology—the NIST Director—was provided Federal government-wide responsibilities for technology transfer, which include coordinating Federal agency activities for the commercialization of technology developed at Federal laboratories. NIST is also the host agency for the Federal Laboratory Consortium for Technology Transfer and plays a lead role in evaluating the performance of government efforts to develop technology through external partnerships and transfer technology to support U.S. economic development.



## SPOTLIGHT ON: RESEARCH FACILITIES

NIST's mission is critically dependent on the quality of the research facilities that house its measurement science and technology development efforts. Scientists and engineers working to push beyond the limits of today's advanced technology require stability.

The aging and obsolescence of NIST's facilities and infrastructure is an ever-pressing issue. These aging facilities and their extensive backlog of deferred maintenance put at risk several areas of research. When making the world's most precise measurements or creating quantum-based measurement tools that are only a handful of atoms wide, the tiniest variations in temperature, or vibrations from increased local traffic, or unreliable electrical current can destroy months of work.

The growth of deferred maintenance needs, which is assessed by an independent team of engineers, across NIST's campuses is a significant strategic issue for NIST that could lead to failing facilities and potentially unsafe conditions. The recent investment in Building 245, the Radiation Physics building on the Gaithersburg Campus, will help address a significant portion of this backlog.

# 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 operating with the agility necessary 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, visits to and from industry, 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.



NIST has identified four long-term trends against which to optimize its capacity—precision measurements, systems, data and modeling, and partnerships and collaborations. These trends reflect broader societal and technological changes that may require fundamental changes in perspective or focus for maximum effectiveness of NIST's programs over the long-term. Generally, these trends are outcomes of a more connected society—one where our economy is based on multifaceted systems-of-systems that present challenges of interoperability, awareness, prediction, and information-sharing. This future requires NIST to continue to develop relevant measurement solutions and to provide trusted data, to convene stakeholders and be a trusted technical expert, and to support highly productive partnerships that address shared challenges.


NIST STRATEGIC FRAMEWORK

A prime example of where NIST will expand its capabilities in precision measurement, data and modeling, systems, and collaboration is in support of continued U.S. leadership in high-performance computing (HPC), as directed in recent Executive Order 13702, "Creating a National Strategic Computing Initiative."

Growth in both basic and applied aspects of new computing technologies has far-reaching industrial applications, national security implications, and economic benefits. Past national investment in HPC has contributed substantially to national economic prosperity and rapidly accelerated scientific discovery in areas such as neuroscience, industrial systems, astronomy, and energy technologies. Leadership in this area is frequently linked to national security and global competitiveness, with other nations making significant investments in this area. Foundational research and development is essential to discover and establish a path forward for HPC after the limits of current semiconductor technology are reached in the next decade.

NIST is an essential part of the National Strategic Computing Initiative because of its continued success pushing measurement science forward to advance computing technologies. NIST will provide impartial expertise and cutting-edge research capabilities to provide enabling platforms to advance the development and testing of new device architectures and computing platforms. NIST will use its strong ties with industry and academia in coordination with other NSCI agencies to ensure that the research goals of the NSCI are aligned with end-user requirements.

NIST's overarching activities supporting the NSCI include:

- Develop measurement science for the physical and materials aspects of future computing technologies, including a focus on alternative state variables that provide low latency, low energy per operation, improved data/communication band-width, and higher clock speed.
- Leverage strengths in device physics, materials design (Materials Genome Initiative), and measurement tool development to address potential logic, memory, storage, and systems concepts needed in an exascale HPC platform.
- Develop the measurement science to support alternative computational paradigms. Continually evaluate the technology pathways, tools, and measurement science that are required to support non-traditional computational paradigms and the classes of problems they may efficiently solve.
- Develop measurements, standards, and guidelines for robustness and security of future generation computing systems and networks that support data-centric computing at scale.
- Create and evaluate the measurement technologies necessary to assess the reliability and uncertainty of results produced by next/future generation computing systems.

## 3.1 PRECISION MEASUREMENTS

Recent advances in computing, communications, and manufacturing technologies have enabled the rapid expansion of sensor use. Sensors measuring physical, chemical, biological, and material properties are being used in everything from military equipment to smartphones. Still, the quantitative performance of these sensors is inadequate for many applications—for example, improved reliability and accuracy are required for manufacturing, defense, and health-care. Such high-performance, mobile sensors can also unlock untold consumer applications, from quantified health to smart-systems for the home.

NIST has the unique mission to address these challenges—bringing precision measurement to the ubiquitous sensing revolution. While continuing to invest in leading-edge metrology research to ensure U.S. leadership in measurement science, NIST will begin to not just ask *what's the best measurement that can be made in a laboratory*, but *what's the best measurement that can be made anywhere*.

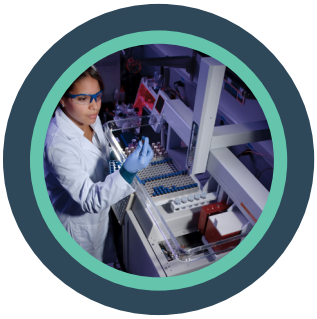
NIST will use its strong ties to industry, state and local governments, and other federal agencies to determine the most important sensor qualities for a given application—for example, size, energy efficiency, robustness, or cost—ensuring maximum utility and optimizing technology transfer. Our proven expertise in nanotechnology, miniaturization, quantum devices, and precision measurement will enable rapid development in this area.

SPOTLIGHT ON: PHOTONICS

The ability to precisely control and accurately detect light is indispensable to advanced manufacturing, high-speed communications, health care, defense, and research. Photonics is the basis for devices from cell phone cameras and night-vision goggles to optical fiber networks for the Internet, sensors used in assembling and operating cars and airplanes, and imaging systems and therapies for the diagnosis and treatment of disease.

The U.S. is the leader in photonics research and applications, but global competition has eroded this leadership, causing a substantial loss of U.S. market share and jobs to overseas competitors. Since maintaining world leadership in photonics is critical to national security the Department of Defense established an Integrated Photonics Institute for Manufacturing Innovation to advance the design and manufacture of photonic integrated circuits.

Ensuring U.S. preeminence in photonics requires significant efforts in the measurement science required to generate, control, and sense light at ever smaller dimensions, shorter time scales, and the extremes of intensities. NIST is investing in the fundamental research underlying the precision measurements necessary to harness the power of light, essentially extracting every possible bit of information from every photon.



## 3.2 SYSTEMS

The complexity of engineered systems is rapidly growing beyond what the world has seen before. These systems cannot be fully understood with conventional analytical and modeling techniques. Furthermore, these systems are being applied in new application areas, forging new partnerships between providers. For example, the proliferation of cyber physical systems (CPS), where remote decision making and control is enabled by analytical techniques and embedded measurements, is expanding the types and complexity of systems operating worldwide. Furthermore, the ability to combine and integrate these new technologies and systems in new and unexpected ways are making new communication modes and standards more necessary than ever. CPS technologies could have an outsized impact on the global economy—by one estimate, the deployment of interoperable CPS technologies could have an impact of $11.1 trillion per year in 2025.[1]

At the same time, improved measurement, modeling, and data analysis techniques are enabling better understanding of existing systems and processes, whether physical, chemical, engineering, or biological, at the system level. Fundamental research into the measurement science of these systems—science elucidating how to understand, predict, and even control such systems—is needed.

To meet the needs of the future economy, one that is increasingly dependent on system-level phenomena, NIST must both invest both in fundamental research to understand the behaviors of systems, and in its convening role to ensure all system stakeholders can benefit from these new technologies.

**SPOTLIGHT ON: DISASTER RESILIENCE**

Natural, technological, and human-caused hazards take a high toll on communities, but the costs in lives, livelihoods, and quality of life can be reduced by better managing disaster risks. Through planning and implementation of prioritized measures, communities can improve their ability to continue or restore vital services faster, and to build back better. That makes them better prepared for future events and more attractive to businesses and residents alike.

A significant barrier to such improvements is the lack of measurement science for assessing the performance of infrastructure and building assets, along with validated cost-benefit tools. Without these tools, there are few options other than to make direct replacements, using the same materials and methods, rather than using innovative approaches that could save the Nation's resources. NIST is investing in measurement science necessary to support community resilience—both at the component and at the system level. By taking an integrated view of vital infrastructure systems and the social and economic realities communities face, NIST is strengthening the resilience of communities across the country.

For example, the NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems[2] provides a practical and flexible approach to help communities to better set priorities and allocate resources to improve their resilience. Using the Guide, communities can integrate resilience into their economic development, zoning, mitigation, and other planning activities.

[1] http://www.mckinsey.com/insights/business_technology/the_internet_of_things_the_value_of_digitizing_the_physical_world

[2] http://www.nist.gov/el/resilience/guide.cfm

## 3.3 DATA AND MODELING

Advancements in computing have created new opportunities for modeling and simulation to replace or support physical experiments and design cycles. This advancement in modeling is supported by a rapid increase—40% year over year—of global data over the past decade, which could lead to research opportunities and business models built on the generation, analysis, and use of new and old data sources.

As processors get faster and less expensive, modeling and data analysis techniques become accessible to smaller businesses at the same time that they tackle larger and more complex problems. Furthermore, while the promise of data-driven innovation is obvious, studies have shown[3] that most data resides in silos, is often not interoperable, and is not easily accessible or machine/human readable, all of which impedes access to the underlying knowledge.

NIST is investing both to ensure that models and data are optimally used to support its own research, and to develop the measurement solutions to maximize the economic potential of modeling and data on U.S. industry.

Modeling and simulation permeates the vast majority of NIST's activities—from supporting the development of world-class measurement techniques, to curating an infrastructure connecting measurement data to predictive models of biology, to developing verified and validated models for industry use. Researchers are able to collect ever increasing volumes of data—whether because the measurements are higher fidelity, more frequent, or broader—presenting both an opportunity and a challenge. NIST is investing in organizations, talent, and infrastructures to ensure that this data is properly analyzed, curated, stored, and shared, maximizing the utility of every measurement.

NIST will develop the measurement science needed to foster continued innovation and deployment of data-driven technology and will provide leadership in characterization and quantification of data quality and the automation used to generate and analyze this data. In addition, NIST will provide the metrology infrastructure necessary to support decision-making dependent on modeling and simulation.

SPOTLIGHT ON: ADVANCED MATERIALS

The task of designing a new material—as well as determining the ideal manufacturing method for that material—is extremely complex, involving many factors that must be balanced. New tools for using advanced models and data repositories promise to significantly cut the cost and time required to design, prototype, and manufacture a new material.

NIST supports the National Material Genome Initiative (MGI)[4], which aims to establish an innovation infrastructure that integrates, tests, and disseminates data, computational models, and experiment for different technology areas and materials classes. NIST is partnering with academia, industry, and other Federal agencies to develop quantitative, predictive computational capabilities founded on both data-driven and physics-based material models, leading to shorter development times, materials of improved performance, and better products. NIST's core expertise will especially contribute to the reliability of these computational approaches

Further, NIST is expanding its capabilities to improve computational approaches to manufacturing new materials. Techniques for materials manufacturing—including formative, subtractive, and additive manufacturing processes—are being tailored to new materials, generating advanced "hybrid" manufacturing technologies for high performance multi-material parts. The widespread use of these techniques will be accelerated by models and methods to determine characteristics inherent to the process and to integrate material specifications and manufacturability information into design and manufacturing processes.

[3] The Open Data Economy: Unlocking Economic Value by Opening Government and Public Data, Capgemini Consulting—https://www.capgemini-consulting.com/resource-file-access/resource/pdf/opendata_pov_6feb.pdf

[4] https://mgi.nist.gov/

## 3.4 COLLABORATION AND PARTNERSHIP

To meet its mission in the face of rapidly evolving priority areas, a widening stakeholder base, and a constrained budget environment, NIST is increasingly partnering with academic, industrial, and governmental institutions. More than ever before, national priorities require the united efforts of diverse participants, and NIST has the unique convening power and technical independence to help bring those participants together.

This trend builds on NIST's historical success with partnerships and stakeholder engagement. NIST's user facilities allow industry, academia, and government researchers to use state-of-the-art technical equipment to accelerate innovation. NIST has long-standing research partnerships with universities in JILA, the Hollings Marine Laboratory, the Joint Quantum Institute, the Institute for Bioscience and Biotechnology Research, and the Joint Initiative for Metrology in Biology, all of which have produced unparalleled technical breakthroughs. The NIST Hollings Manufacturing Extension Partnership (MEP) program partners with Centers in every state across the country to help small and mid-sized U.S. manufacturers create and retain jobs, increase profits, and save time and money.

More recently, NIST has worked with diverse stakeholders to develop standards frameworks that promote interoperability and measurement science. Examples of these frameworks include the Smart Grid Framework and Roadmap[5] and the Framework for Critical Infrastructure Cybersecurity[6]. These frameworks, which have been well-received by their stakeholders, provide the foundation for interoperability and performance in these national priority areas.

NIST's Center of Excellence program[7] provides an interdisciplinary environment where researchers from NIST, academia, and industry collaborate on emerging areas of basic and applied research and innovations in measurement science. This program expands NIST's capabilities in areas of critical national need. Over the past two years, NIST established three Centers of Excellence. In FY 2014, NIST partnered with a consortium led by Northwestern University to establish the Center for Hierarchical Materials Design (CHiMaD), which focuses on advanced materials. NIST expanded the Center of Excellence program in FY15 with two additional Centers: the Center for Risk-Based Community Resilience Planning led by Colorado State University and the Center for Statistics and Applications in Forensic Evidence led by Iowa State University.

**SPOTLIGHT ON: SPECTRUM SHARING**

In 2015 a record-breaking auction licensed 65 MHz of spectrum currently occupied by Federal incumbents. Wireless carriers are eager to activate this spectrum to recoup their sizable investment, but measurements and analyses that can verify coexistence and sharing strategies have not been made, and in some cases the measurements have not been developed. NIST is increasing its measurement science capability and capacity to better support this critical technology area.

Through the Center for Advanced Communications, a partnership between NIST and sister Commerce bureau National Telecommunications and Information Administration, NIST supports the National Advanced Spectrum and Communications Test Network (NASTCN), established in 2015. NASCTN is a network of government, academic, and commercial capabilities able to coordinate the use of intellectual capacity, modeling and simulation, laboratories, and test ranges to meet national spectrum interests and challenges. NIST's unique measurement science expertise underpins NASCTN, and will give the Federal and commercial users of the wireless spectrum a third-party organization that can provide the accurate data, trusted models and objective analysis needed in order for regulators to make informed decisions about spectrum-sharing polices.

[5] http://www.nist.gov/smartgrid/framework3.cfm

[6] http://www.nist.gov/cyberframework/

[7] http://www.nist.gov/coe/