THREE-YEAR PROGRAMMATIC PLAN

FOR THE

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

U.S. DEPARTMENT OF COMMERCE

FISCAL YEARS 2009-2011

FEBRUARY 4, 2008

1 Executive Summary: *NIST Strategies for Success*

The America COMPETES Act calls for submission of a three-year programmatic plan for the Commerce Department's National Institute of Standards and Technology (NIST) concurrent with submission of the President's budget to Congress. This plan covers Fiscal Years 2009-2011.

The U.S. Commerce Department's National Institute of Standards and Technology (NIST) is the premier federal agency supporting the measurements and standards requirements of the Nation. Recently, numerous prestigious publications—such as The National Academy of Science's *Rising Above the Gathering Storm* and *Compete America* from the Council on Competitiveness—have highlighted the importance of basic scientific discovery and innovation to economic growth and well-being. In critical technical areas, including biotechnology, nanotechnology and technologies to address global climate change, increased support for the physical sciences and for the development of critical measurement solutions is needed. These new and advanced measurement capabilities hold the potential to revolutionize our understanding of the world and enable the next generation of technologies.

With the President's American Competitiveness Initiative (ACI) and the passage of the America COMPETES Act, both the President and Congress recognize that "America's economic strength and global leadership depend in large measure on our Nation's ability to generate and harness the latest in scientific and technological developments and to apply these developments to real world applications."[1] The ACI specifically highlights NIST as one of three key federal agencies that support basic research programs in the physical sciences and engineering. This research is critical to the innovation that underlies the United States' future.

Accordingly, the ACI calls for doubling, over 10 years, the funding for innovation-enabling research at NIST, the National Science Foundation, and the Department of Energy's Office of Science. NIST is a high-leverage federal research agency that performs high-impact basic research and supports the successful technical translation and everyday use of economically significant innovations. Key areas of NIST research include new materials and processes, nanotechnology, electronics, information technologies, advanced computing, biosciences, manufacturing, and new energy sources such as hydrogen.

In today's fiercely competitive global environment, the cutting-edge measurement technologies and rigorous standards provided by NIST are one essential component of U.S. innovation and competitiveness. New measurement capabilities pave the way to next-generation disruptive technologies that transform established industries and launch some entirely new sectors.

Across the innovation spectrum—from laboratory to marketplace—measurements are a necessary means to important ends. Businesses, universities, and government laboratories need access to ever-improving measurement capabilities if the United States is to remain a technology leader and reap the resulting economic benefits.

Successful development and introduction of important next-generation products will hinge on progress on several measurement-related fronts. For example, realization of the promise of quantum computing, nanoscale devices, and other frontier technologies will require advances in the science of measurement. As the Nation faces the challenges and opportunities of nanotechnology, industry is limited not only in its ability to measure key parameters but also in its ability to identify which key parameters must be measured to meet anticipated environmental, health, and safety regulations. In a variety of ways, breakthroughs in measurement capabilities may be necessary to clear a path to market. In some cases, innovation has been stalled due to lack of measurement technology to assure and verify performance and quality or to resolve questions regarding potential risks and hazards that emerging technologies may pose.

INVESTMENTS IN MEASUREMENT YIELD BENEFITS TO THE ECONOMY

The connection between NIST's investments in measurements and standards clearly is linked to innovative and economic benefits. NIST has been a recognized leader in conducting rigorous economic evaluation of its programs' impacts, performing, or sponsoring these studies on a regular basis since 1992. The combined average of all studies shows that the work in those programs studied has yielded a benefit to cost ratio of $44 for every $1 invested at NIST. These studies evaluate the long-term impacts that derive from individual or, in some cases, a set of related projects within a single program. Over time, the projects cover a wide range of technologies and industries and provide quantitative estimates and qualitative assessments of the economic impact resulting from the various technology infrastructures. Why are there such large benefits? The scientific work done by NIST is highly infrastructural and contributes to the technological backbone so vital to innovation.

To ensure that NIST continues to meet the Nation's highest priority measurement and standards needs, NIST is focused on optimizing its outreach and interactions with industry and academia. These efforts include the United States Measurement System survey, which has identified over 700 key measurement barriers to innovation facing U.S. industry. They also include the development and implementation of new models of public/private partnerships to promote directed basic research in key technological sectors with the ultimate goals of increasing the Nation's return on its scientific investment and collapsing the time scale of technological innovation. Moreover, they include an emphasis on maximizing the use and adoption of NIST's knowledge and technology to enable the private sector to further develop and commercialize ideas stemming from the Institute's lab-based research. Each of these efforts is specifically designed to maximize NIST's impact.

The ACI and the passage of the America COMPETES Act provide an unprecedented opportunity to further enhance NIST's contributions to innovation and competitiveness. Unfortunately, Fiscal Year 2008 appropriations put NIST at risk of falling off of the doubling path. Those appropriations do not provide funding for NIST's laboratory research and facilities efforts at the President's request level for the ACI. NIST will make every effort to optimize the funds provided, but the lower funding provided compared to the President's budget request will have negative impacts on NIST and its customers and partners in industry, academia, and other agencies. Those impacts include a real loss in timely research that yields positive benefits for the nation.

The President's FY 2009 request for NIST would get the Institute back on track to double NIST's budget over 10 years, a key element of ACI that would enable NIST to continue to aggressively lay the science and technology foundation recommended by so many reports and proclamations on U.S. innovation and competitiveness.

It is paramount that NIST strengthen its current core competencies and move rapidly and wisely toward realizing the vision of being the world's leader in creating critical measurement solutions and promoting equitable standards. Well-targeted measurement and standards investments are a proven path to stimulate innovation, foster industrial competitiveness, increase economic security, and improve the quality of life of all Americans. To achieve these ends, NIST directs future planning toward addressing three overarching strategic goals:

1. Help the United States to drive and take advantage of the increased pace of technological change;
2. Foster more efficient transactions in the domestic and global marketplace; and
3. Address critical national needs.

Measurement Innovations Add Up to Big Savings for Semiconductors

A new report* from the National Institute of Standards and Technology (NIST) shows that investment in measurement science has and will continue to have a dramatic effect on innovation, productivity, growth and competitiveness in and among high technology sectors. Citing the semiconductor industry as a case in point, the analysis, prepared for NIST by RTI International (RTI), estimates that the $12 billion spent on advancing measurement capabilities during the decade beginning in 1996 will have saved that sector more than $51 billion in scrap and rework costs by 2011—a net benefit of approximately $39 billion ($17 billion net present value).

RTI estimates that for every dollar spent on measurement, the industry as a whole saw a $3.30 return. (Dollar amounts represent 2006 dollars adjusted for inflation.) The report found that the strategic focus on measurement technologies pursued by the International Technology Roadmap for Semiconductors (ITRS), a consortium of chip manufacturers and related stakeholders, benefited both the industry and consumers through the reduction of defect rates and the miniaturization of feature size. The advances fostered through this effort, among others, resulted in lower costs, higher product quality and ever faster processing speeds.

Measurement technology has allowed the industry to keep up with "Moore's Law," which predicts the number of transistors per chip will double every two years. By the early 1990s, the industry realized it would no longer be possible to satisfy this benchmark without the ability to manipulate nanoscale-sized features. The report credits the initiative to augment nanoscale measurement capabilities outlined in the ITRS and its predecessor as one of the factors that helped manufacturers to increase the possible number of transistors per chip from 3.1 million in 1996 to 1.7 billion in 2006 while making marked improvements in quality, design, software and interoperability.

The report underlines the importance of measurement science to the semiconductor industry and highlights several areas that need further improvement if the industry is to stay on pace. These areas include the need for new standards for measuring features lengths at 32 nanometers, new techniques for controlling radio-frequency electromagnetic energy and high-frequency magnetic fields, and better chemical and materials standards, as well as new and more accurate calibration, interoperability and test standards.

RTI gathered the information for this analysis through surveys and other means. The answered queries accounted for more than 80 percent of the semiconductor industry, and the results were taken to be representative of the industry as a whole. The results may also be viewed as conservative in that RTI was able to quantitatively estimate productivity impacts but not increases in quality.

**Economic Impact of Measurement in the Semiconductor Industry* is available on the NIST Web site at http://www.nist.gov/director/planning/policy_studies.htm

To accomplish these strategic goals, NIST must be successful in another goal:

4. Enhance the effectiveness and efficiency of NIST staff and equipment.

To succeed, NIST must plan strategically. Four pillars serve as the foundation for planning and increasingly help to guide the organization:

1. Enhanced stakeholder outreach and identification of critical measurement and technology challenges;
2. A strategic multiyear investment framework;
3. Development of the infrastructure to optimize and support the Nation's technological and organizational innovation—and the staff and equipment so that NIST can succeed; and
4. Rigorous evaluation of all NIST investments.

This approach enables NIST to continually reevaluate its portfolio of investments to ensure the areas of focus in which NIST is fully engaged, including nanotechnology, neutron research, and quantum science and areas that may be targeted for future expansion, including the biosciences, sustainable development, and communications, are addressing the most pressing challenges and are targeted to have the highest impact. Furthermore, the framework allows NIST to retain the flexibility necessary to develop programs that address immediate national needs whether they relate to voting standards and technology, IT security, or public safety.

The ACI and the COMPETES Act underscore the importance of NIST in continuing to provide the cutting-edge measurement science that underlies U.S. achievements in science, technology, and innovation. The Institute's products and services will be even more critical in this first part of the 21st century than they have ever been in the 107-year history of the organization. This makes it essential that NIST manage its programs—ongoing and planned—for maximum impact. The strategic approach:

- identifies and targets critical measurement and technological problems facing the Nation and its economy;
- leverages the resources and expertise of the NIST programs and staff;
- stimulates collaborative research between NIST and its partners in industry and academia against basic research needs of mutual interest;
- develops the capabilities needed to lower the risk associated with basic and early stage research;
- enhances the training and expertise of U.S. scientists and engineers particularly in the area of measurement science; and
- provides management tools to achieve business success.

This multipronged approach will shorten time between discovery, innovation, and deployment and enhance U.S. competitiveness, and improve the economic security and quality of life of all Americans.

2 Who We Are: *NIST's Mission, Vision, Core Values, and Competencies*

NIST's mission, vision, and core values form the foundation for organizational performance. They are guiding ideals, setting the standards for how we serve our customers in industry, academia, and government, maintain public trust and confidence, carry out our individual jobs and meet our organizational responsibilities, and treat our fellow employees. NIST and its employees, collectively and individually, aspire to each of these values as they form the foundation of the Institute's core operating principles.

2.1 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.

2.2 Vision

Be the world's leader in creating critical measurement solutions and promoting equitable standards. Our efforts stimulate innovation, foster industrial competitiveness, and improve the quality of life.

2.3 Core Values

NIST has four core values:

1. People: We value and support an inclusive, engaged, and diverse workforce capable of fulfilling the NIST mission;
2. Integrity: We are objective, ethical, and honest;
3. Customer focus: We anticipate the needs of our customers and are committed to meeting or exceeding their expectations; and
4. Excellence: We expect world-class performance and continuous improvement in all we do.

2.4 Core Competencies

The NIST core competencies are those activities and capabilities that define how NIST provides value to the Nation and its stakeholders. These competencies set us apart from other agencies and make NIST unique in its role within the United States Government. They are:

- measurement science,
- rigorous traceability, and
- development and use of standards.

3 Where We Are Going: *Positioning NIST for the Future*

The 21st century will be defined by high-technology innovations that fundamentally change the products and services available and the way they are manufactured and provided. These innovations will both depend upon and change the business models of U.S. companies and other organizations. They also will have an enormous impact on our quality of life. These advances will arise from basic research now beginning in a number of fields such as nanotechnology, quantum science, and alternative energy—all of which are directly impacted by research conducted at NIST. Successful innovations also will depend upon the research, services, and assistance NIST provides to organizations as they seek to develop, commercialize, market, and utilize advances in these and other areas.

NIST is constantly reevaluating its ongoing research and developing plans for new research programs in critical areas to ensure its research is targeted to have the greatest impact and that the Nation receives the best possible return on its investment. To facilitate this process, NIST has assessed both external drivers (Administration and congressional priorities, National Academies studies, and stakeholder input), and internal capabilities and gaps in order to define potential target areas for new projects and programs. This analysis resulted in the development of a system to guide and focus NIST's research and outreach efforts, which consists of strategic goals and a strategic planning framework. To meet our mission and guide our planning, we have developed the following strategic goals for NIST:

1. Help the United States to drive and take advantage of the increased pace of technological change;
2. Foster more efficient transactions in the domestic and global marketplace; and
3. Address critical national needs.

To accomplish these strategic goals, NIST must be successful in another goal:

4. Enhance the effectiveness and efficiency of NIST staff and equipment.

To succeed, NIST must plan strategically. Four pillars serve as the foundation for that plan and increasingly will help to guide the organization:

1. Enhanced stakeholder outreach and identification of critical measurement and technology challenges;
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4. Rigorous evaluation of all NIST investments.

Through this approach, NIST is planning to focus on programs that will:

- address critical national needs and measurement barriers to innovation;
- improve the capacity and capability of the NIST laboratories;
- form new and strengthen existing partnerships with industry and academia; and

- develop novel mechanisms to stimulate the transfer of knowledge between NIST, industry, and academia.

Over the next three years, NIST will place a very heavy emphasis on each of these means to achieve our mission. Our ability to do so will be affected, of course, by the resources made available to NIST by the Administration and Congress.

NIST received $439.6 million of its $500.5 million request for Scientific and Technical Research Services (STRS), which primarily funds NIST labs. That is an increase of $5.3 million or 1.2 percent, over the FY 2007 enacted level compared with a requested increase of $66.1 million or 15.2 percent. (This does not include a congressionally directed award of $893,000).

This means that research areas critical to U.S. innovation will not be advanced as aggressively as originally proposed. For example, the impacts include:

- Nanotechnology: Slows development of accurate detection and measurement methods and standards. In turn, this reduces industry's ability to exploit the economic potential of nanotech safely, limits the development of next-generation, nanotechnology-based cancer therapies, and weakens consumer confidence in nanotech products. These will be a consequence of the lack of NIST measurement tools which are key to the determination of potential toxicity and environmental impacts of nanoparticles.

- Quantum computing: Postpones by at least a year progress in transformational research that can increase the nation's competitiveness. Delays development and implementation of absolutely secure solutions for financial and national security communications.

- Climate change: Inhibits improvement of the accuracy of climate change measurements, which could lead to savings in satellite programs and assist in evaluation of policy options. Specifically, calibrations of satellite sensors needed to quantify measures of solar irradiance and terrestrial temperatures will be delayed.

- Earthquake, flood, and wildfire-resistant structures: Opportunities to reduce $52 billion in annual natural disaster-related losses will be delayed. Progress will be slowed in developing model building codes, standards and tools for evaluating seismic strength as well as wind- and wildfire-resistance of new and existing buildings and communities.

It also means that NIST falls $13.5 million short of the amount needed to cover salary increases and other anticipated costs, requiring several actions. Consequently, NIST will slow down new hires with specialized skills and will not be able to bring on board the estimated 300 additional staff and guest researchers anticipated with the budget initiatives requested by the President. NIST managers are reviewing laboratory and administrative activities to ensure that ongoing high priority projects receive the funding that they need and that all funds are used as efficiently as possible.

As part of the ACI, NIST received $79.1 million of its requested $93.9 million for two new facilities initiatives and for operational maintenance, major repairs and safety of the NIST campuses. (This does not include congressionally directed awards of $51.3 million and a $30.1 million competitive construction grants program not requested by the President.) These two facilities initiatives are multi-year projects already under way: expansion of a neutron research center (NCNR) in Gaithersburg and laboratories in Boulder -- improvements that are critical in order for NIST to continue to conduct cutting-edge research for U.S. science and industry. The NCNR project is projected to provide world-class facilities to an additional 500 researchers each year.

To compensate for the shortfall, NIST has adjusted its overall facilities plans in order to proceed with the two major projects. Consequently, NIST will slow down its program to reduce the backlog of deferred maintenance projects on existing facilities. This increases the chances of unanticipated major equipment outages and temporary loss of facilities use, resulting in higher repair costs and loss of researchers' productivity.

The President's FY 2009 request for NIST would get the Institute back on a doubling track - enabling NIST to continue to aggressively lay the science and technology foundation recommended by so many reports and proclamations on U.S. innovation and competitiveness.

Our strategy and implementation will be aligned to reflect actual appropriations and potential additional assignments from Congress. NIST will follow these strategic goals and utilize the four pillars as a foundation for the Institute's planning.

This approach enables NIST to continually reevaluate its portfolio of projects to ensure that the areas of focus into which NIST recently has expanded (such as nanotechnology, neutron research, and quantum science) and areas that NIST may target for expansion (such as the biosciences, climate change, green manufacturing and sustainable development, and communications) are addressing the most pressing challenges and are targeted to deliver the highest impact. The strategic planning framework is not a rigid multiyear plan. Rather, it allows NIST to retain the flexibility necessary to carry out programs that address immediate national needs whether they relate to voting standards and technology, IT security, or public safety.

It is noteworthy that this approach continues and intensifies NIST’s long-time focus on both stakeholder drive and independent evaluation. NIST must constantly reevaluate its portfolio of investments and priorities, as well as its organizational structure and its approach to attracting and retraining an excellent—and increasingly diverse—staff.

4 Realization of NIST Goals – Pillar One: *Enhanced stakeholder and customer outreach and identification of critical measurement and technology challenges*

With the advent of the American Competitiveness Initiative (ACI) and the passage and signing into law of the America COMPETES Act [10], the importance of NIST measurement and standards activities to U.S. economic competitiveness and innovation has been put in the spotlight. To ensure that NIST programs deliver the highest impact, the Institute is committed to identifying the most critical measurement, standards, and technological challenges of the Nation and our stakeholders in industry, academia, and other government agencies.

A primary source of NIST's strategic planning input is the guidance provided by both the Administration and the Department of Commerce (DOC). Input from the Administration is drawn from a number of sources, including the R&D Budget Priorities Memoranda from OMB and OSTP [2-6], reports and studies from the President's Council of Advisors on Science and Technology (PCAST), and the publications of the National Science and Technology Council (NSTC), which is a critical tool for coordinating science and technology efforts across the Federal Government. NIST's direction is also influenced by the strategic planning of DOC [8]. The DOC strategic plan outlines the efforts that the Department is making over the coming years to maximize U.S. competitiveness and enable economic growth, foster science and technological leadership, and promote environmental stewardship. The DOC plan highlights the importance of NIST's efforts in creating the conditions that promote innovation, entrepreneurship, and competitiveness.

Naturally, NIST also takes into account input and legislative directions from Congress. The America COMPETES Act [10] is the most recent and far-reaching guidance in the form of authorizations for programs. Other legislation often contains specific and very diverse tasking. In the past several years, NIST increasingly has been called upon to address critical national needs via these statutes. Prime examples are the work that NIST was called on to perform related to voluntary voting standards by the Help America Vote Act of 2002 [9], and to lead the multiagency National Earthquake Hazards Reduction Program (NEHRP), as called for by the NEHRP Reauthorization Act of 2004.

NIST also looks to the broader science and technology policy community for information, recommendations, and advice. Input from sources such as the National Academies and non-partisan, non-governmental organizations concerned with U.S. competitiveness and science and technology policy are a valuable source of strategic input. In 2007, the National Academies published an influential report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* [10] that contains much useful information and discusses many topics relevant to the development of NIST's strategic plan. In particular, *Rising Above the Gathering Storm* emphasizes the importance of innovation and technological change to the U.S. economy.

The report goes on to prioritize the steps that federal policymakers could take to enhance the science and technology enterprise so that the United States can remain a globally competitive power in the decades to come. Groups such as the Council on Competitiveness [13], a collection of corporate CEOs, university presidents, and labor leaders dedicated to the cause of enhancing the U.S. economy through innovation, also are drivers for NIST planning activities. By drafting position papers, analyses, and initiatives on technological topics of interest to NIST, groups such as these support NIST's strategic planning by collating facts and articulating how and what innovations stimulate the economy.

In addition to input from the Administration, Congress, and the S&T policy community, NIST actively seeks input from its stakeholders and customers through workshops, conferences, and the everyday outreach of NIST researchers and managers to the private sector to define the most pressing measurement and standard needs. A prime example of such efforts is the recently completed assessment of the United States Measurement System (USMS). With the goal of identifying critical measurement gaps that act as a barrier to innovation, this study identified more than 700 measurement needs. Examples of some of the measurement challenges identified include:

- the need for versatile, high-accuracy methods to measure the three-dimensional geometry of manufactured products;
- the need for tools for measuring the properties of nanodevices and materials;
- the need for reliable and unbiased performance data to speed the adoption of new and innovative technologies in the building/construction sector;
- the need for new sensor technologies for in-line, real time, and continuous monitoring of process variables in chemical manufacturing; and
- the need for standards and more accurate measurement technologies in the health care and biosciences sector to enable advanced DNA analysis, sensor-based proteomics for early cancer detection, and new imaging modalities in magnetic resonance imaging.

The USMS study also singled out the following actions to be taken as next steps to enhance the Nation's measurement capabilities and to accelerate technological innovation:

- promote awareness of critical measurement needs identified in this assessment throughout the measurement research community;
- identify strategies to bolster the effectiveness of USMS solution providers and accelerate the time-to-market of measurement technology;
- foster collaboration to accelerate measurement breakthroughs;
- encourage industrial sectors to identify and prioritize measurement needs;
- identify shared measurement needs and opportunities for synergy across industries and research areas; and
- foster strategic public-sector investments in measurement R&D to accelerate technological innovation by:
    - keeping end users and solution providers informed of federal measurement capabilities;

- incorporating insights from this assessment into strategic and program plans; and
- establishing an explicit measurement innovation agenda.

This assessment, carried out with partners from industry, academia, and government, focused specifically on measurement-related barriers to the multistep process of technological innovation concluding with the introduction of new technology into the marketplace. Whether new capabilities, improvements in measurement-related services, or other actions, solutions to critical measurement needs were determined to be necessary means to innovation success.

Over the next three years, NIST will use this assessment to focus its own work in support of U.S. innovation and competitiveness. The report's results and findings, along with input gathered in follow-up activities, will inform NIST's strategic planning decisions. NIST has now implemented this as an ongoing and continuous process.

Finally, NIST strategic planning also is influenced by advice and input from external advisory and assessment committees and panels created explicitly to make recommendations about NIST's organizational health, programmatic planning, and budget. (See Section 7, "A Rigorous Evaluation Strategy") For example, chartered by federal legislation, the NIST Visiting Committee on Advanced Technology (VCAT) made up of distinguished academic and industry leaders provides an important input to NIST strategic planning with the unique perspective of industry, which makes up a key portion of our customer and stakeholder base. Increasingly, NIST has been soliciting the VCAT to provide high-level advice about the "what" and the "why" of areas in which NIST is or might become engaged. This trend is expected to continue during the next three years.

5 Realization of NIST Goals – Pillar Two: *A Strategic Multiyear Investment Framework*

The ability to innovate and apply new technology is central to our Nation's future. In fact, the fiercely competitive global economy demands that innovation become a core driving force, not only for businesses and industries but also for the country as a whole. Advanced measurement capabilities are essential to innovation—in every major economic area and at every stage of the innovation process. Research represents the inception of revolutionary technologies of the future. Progress in such research depends on advanced measurement capabilities that are fundamental to the exchange of the resulting new knowledge and its refinement into experimental applications and commercial success.

Biotechnology, advanced materials, IT infrastructure, and communications are just a few of the key technology areas that demand improved measurements and standards if we are to more fully exploit their potential. It is critical that NIST manage its resources and potential growth in ways that strengthen our current core competencies and move NIST forward toward realizing the Institute's vision: *to be the world's leader in creating critical measurement solutions and promoting equitable standards. Our efforts stimulate innovation, foster industrial competitiveness, and improve the quality of life*. As such, NIST has developed the following system for multiyear planning of investments. This framework is not meant to restrict topics of research, but rather to act as a guideline to ensure that expansions of NIST research efforts are aligned with national needs and priorities and further NIST's strategic goals:

1. *Help the United States to drive and take advantage of the increased pace of technological change;*
2. *Foster more efficient transactions in the domestic and global marketplace;*
3. *Address critical national needs; and*
4. *Enhance the effectiveness and efficiency of NIST staff and equipment.*

The demand to prioritize resource needs applies not only to areas of growth but also to current research programs. It is essential to identify research programs and competencies that are no longer as relevant and could be phased out to ensure that maximum resources are allocated to those efforts likely to have the biggest impact. The NIST investment framework is designed to be flexible enough to account for the increased complexity, interdisciplinary nature, and quickening pace of scientific research—along with changes in the way partners and competitors approach this research. Our approach is intended to be updated on a regular basis.

General Considerations for Research:

In general, research efforts at NIST are encouraged to:

- Be interdisciplinary. Often it is at the boundaries between disciplines where dramatic advances occur. In particular, many of the recent initiatives have shown common barriers or challenges that should be explicitly discussed in the proposals, namely: complexity, data mining/fusion/interoperability, as well as the need for improved measurements; and
- Create partnerships with industry and academia in order to leverage a broader technical expertise and to enhance the diffusion of knowledge.

Investment decisions will take into consideration whether initiatives, when appropriate, make use of interdisciplinary collaborations, and whether they fully take advantage of external outreach opportunities and/or foster new partnerships with the scientific community outside of NIST.

NIST R&D Investment Framework through FY 2011

To maximize the impact of NIST's proposals for new research, initiatives will be targeted to the following four broad categories:

1. Initiatives that strengthen current core competencies (Strategic Goals 1 and 2)
Increased funding to current core competencies that are high priority yet underfunded will be considered. Any proposals aimed at addressing this focus area must clearly demonstrate:

- relevance of the core competency to NIST's mission and vision;
- priority of the core competency; and
- that reallocation of existing resources is not possible or is insufficient to address funding shortfalls.

2. Research that addresses the most strategic and rapidly developing technology areas (Strategic Goals 1 and 2)
The United States and the world are entering a period of dramatic change. A sustained period of significant investment in the basic sciences is leading to technological advances that have the potential to dramatically alter the world in which we live. This century will be defined by new technologies that fundamentally change the products and services available, the way they are manufactured and provided, and the impact on our quality of life. Yet before these advances can be realized and commercialized, there is often a measurement barrier to further progress and innovation. Based on an analysis of trends and national priorities stemming from multiple sources including the National Science and Technology Council, the National Academies, the USMS, and others, NIST has identified the following fields as key priority strategic thrusts for future NIST research initiatives:

- biotechnology
- advanced materials
- IT infrastructure and communications

3. Investment that expands the frontiers of measurement science (Strategic Goals 1 and 4)

This focus area for investment addresses the kinds of research that are critical if NIST is to fulfill its vision of becoming the world's leader in creating critical measurement solutions. Investments that support either of the following will be considered a priority:

- research on the fundamental aspects of measurement or measurement tools and technologies; and/or
- investment in innovative infrastructure necessary for NIST to remain a preeminent measurement science and standards institution.

NIST's work in quantum science and atomic, molecular, and optical (AMO) physics are prime examples of investment in fundamental measurement science opening up entirely new frontiers and possibilities for metrology where NIST has indisputable global leadership.

The NIST Center for Neutron Research expansion and the improvements to NIST Boulder facilities are examples of investments in cutting-edge infrastructure necessary for NIST to remain the preeminent measurement science institution. For example, work at the NIST Boulder facility is at the cutting edge of measurement science and will impact important technological areas, including nanotechnology, homeland security, telecommunications, and time measurement. Because of the advanced nature of NIST's work, the smallest fluctuations in laboratory conditions can disrupt our ability to make extremely sensitive measurements such as:

- measurements of properties of materials at the single atom level to support nanotechnology research and development as part of the National Nanotechnology Initiative;
- stringent timing and synchronization measurement to be provided by next-generation atomic clocks that will perform at the 10^{-18} second uncertainty level (equivalent to one second in 30 billion years) and will support a wide range of future commercial and security applications, including telecommunications, higher-performance GPS, high-speed computing, space exploration, and scientific research;
- measurement of forces equivalent to less than a billionth of a gram to study how cells and molecules function for new knowledge in biotechnology and health care; and
- precision counting of streams of photons (individual particles of light) to support research on secure quantum communications.

4. Research that addresses critical national needs (Strategic Goal 3)

Regardless of the comprehensive nature of an organization's strategic planning efforts there will always be critical issues arising outside the boundaries of conventional planning that require an immediate response. Some of these critical national needs may be mandated by either the Executive or Legislative Branch (e.g., Federal Information Security Management Act, Help America Vote Act, National Earthquake Hazards Reduction Program, Health IT Standards). No matter their origin, NIST needs to ensure that the NIST program is focused and properly resourced for success. Examples of additional pressing national needs where NIST may play a valuable role include:

- Manufacturing – manufacturing accounts for over 11 percent of the GNP with research and development of high technology manufacturing having a significant impact on the growth of the U.S. economy;
- Energy demand and supply – especially in terms of energy efficiency or standards and technical infrastructure to support alternative energy sources (e.g., hydrogen and biofuels);
- Climate change – as called out by the Climate Change Science Program (e.g., studies on atmospheric composition, global water cycle, global carbon cycle, etc.); and
- Safety in commerce – including measurements and standards related to food safety or product safety, both of which are becoming more important as the global economy expands into developing regions.

Summary

By targeting NIST's investments against the four focus areas outlined above and continually reviewing those areas in the context of changing national needs and scientific and technological developments, we will continue to ensure that NIST remains an essential component of continued economic growth and competitiveness, a world leader in measurement science, and a flexible and responsive organization capable of addressing society's most pressing needs.

The implementation of the investment framework to date can be seen in Appendix A. For each of the programs described, the Appendix outlines the problem or challenge addressed by the effort, a brief summary of the program structure and approach, and the expected impacts if successful. Further information on NIST's efforts to support high-risk R&D and to recruit and retain high-caliber scientists can be found in Appendices B and C respectively.

6 Realization of NIST Goals – Pillar Three: *Development of the infrastructure to optimize and support technological innovation*

Today the United States is part of a vibrant global economy and as such is exposed to much higher levels of competition than ever before. To maintain our leadership we must adapt our mechanisms and policies for investing in science and technology and business expansion to meet the challenges of the 21st century in ways that maximize the return on our investments and increase our capacity and capability for innovation.

NIST is intent on developing and utilizing a broad array of tools and programs to create an infrastructure for technological innovation. These tools and programs will allow NIST to optimize investment in R&D and to leverage the resources and expertise of the NIST core programs. Flexible and coordinated extramural research and outreach programs are needed to provide the solutions necessary to maintain U.S. competitiveness and promote innovation across the entire R&D enterprise. Critical components of this innovation infrastructure include:

- **Maintaining and improving the technical expertise of the American workforce –** NIST's collaborative research programs help the technical workforce stay current with the most advanced technologies and aid students in developing the technical skills to excel in the future. In many respects, NIST helps to train the next generation of metrologists—experts in measurement science. We will focus more intently on this role.
- **Improve manufacturing and service sector creativity, efficiency, and productivity –** NIST is committed to helping U.S. corporations be competitive by disseminating and evaluating best practices for quality and performance excellence in areas of: leadership; strategic planning; customer and market focus; measurement, analysis, and knowledge management; human resource focus; process management and results.
- **Accelerating technology development, deployment, and adoption –** NIST has a strong focus on innovation and growth services for U.S. industry. The future competitiveness of U.S.-based industry depends upon the skillful development, adoption, and implementation of innovative technology and market-driven knowledge, and NIST must increasingly focus on its role in enabling this transfer of knowledge in order to meet the needs of multiple technology sectors.
- **Establishing new models for R&D partnerships –** NIST is exploring and experimenting with new models of public/private partnerships to identify and overcome major precompetitive technology hurdles that impede progress within specific industry sectors critical to U.S. competitiveness. These new funding models would support high-risk, long-term, "use-inspired" basic research in critical technological sectors conducted at universities but driven by the long-term needs of industry. The newly announced agreement between NIST and the Nanoelectronics Research Institute (NRI) is an example of such a partnership. The cooperative agreement provides $2.76 million to fund research at U.S.

universities in the area of nanoelectronics with the intent of developing a new logic switch to replace the current CMOS chip that is the basis of today's semiconductors. (For more information see <http://www.nist.gov/public_affairs/releases/src.html>)

- **Grants and Contracts for Strategic Planning and Road Mapping:** NIST uses these useful tools to foster collaboration within industrial technology sectors aimed at developing a shared vision of common long-term research challenges necessary for continued advancement or exploitation of that particular technology.
- **NIST Technology Fellowships:** NIST plans to develop tools to help facilitate the diffusion of knowledge and contribute to the innovation enterprise by providing the opportunity for promising students and prominent researchers to work collaboratively for an extended period in a new setting. This fellowship would pay travel and living expenses for domestic (U.S. citizen) students, professors, or industry scientists or engineers to work at NIST, or for NIST staff to work in an academic or industrial setting. (NIST currently has no industrial fellowships, although the Institute does have numerous guest researchers from industry.) These prestigious fellowships would increase the circulation of U.S. scientists and engineers across the entire R&D spectrum, thereby increasing the flow of knowledge needed by our Nation to better compete in the 21st century. By law, NIST's capacity for domestic fellowships is currently limited to 1.5 percent of the NIST budget.*
- **Measurement Science Research Grants:** Grants to universities and the private sector that complement research efforts at NIST in a particular initiative area are an effective tool in expanding NIST's R&D efforts "beyond the fence" because they aid in the development of new ideas and promote scientific growth. The measurement science grants provide a mechanism to expand and increase the impact of the measurement science, standards, and technology development efforts of the NIST laboratories. These efforts underpin our Nation's ability to innovate, lead to new products and services, encourage and enforce fair and equitable exchange of products in the marketplace, promote public safety and security, and enhance the quality of life. NIST has regularly relied on these grants and now anticipates expanding the use of this tool as resources expand.

*text corrected 3/3/08

7 Realization of NIST Goals – Pillar Four: *A Rigorous Evaluation Strategy*

NIST evaluation strategy involves explicit metrics-based evaluation of all programs, continued evaluation under the NIST Performance Measurement and Evaluation System, and rigorous microeconomic cost-benefit studies. This strategy leverages NIST's experience with metrics and evaluation and ensures that the Institute will allocate resources effectively and will be able to demonstrate a return on investments. NIST takes seriously the input and feedback provided by these evaluations and adjusts its priorities and programs accordingly.

NIST's evaluation strategy is designed to follow programs and projects from the initial planning stages all the way through to an analysis of impact and consists of three major stages:

- merit-based competition for the initiation of newly funded projects and the redirection of existing funds;
- regular monitoring of program accomplishments to ensure the effective and efficient operation and management of programs; and
- long-range impact analysis of programmatic achievements.

The NIST evaluation strategy is initiated at the earliest stages of the programmatic planning process with each idea for a new program going through a rigorous merit-based competition that evaluates not only the technical merit of the proposed work but also the relevance of the proposed project to national R&D priorities (as defined by the Administration, Congress, the National Academies, and other sources), the ability of the proposed work to address the identified challenge, and the fit of the proposed work to NIST's mission. To address these issues each new proposal from researchers is required to answer the seven modified "Heilmeier" questions:

1. What is the problem, and why is it hard?
2. How is it solved today and by whom?
3. What is the new technical idea, and why can we succeed now?
4. Why should NIST do this?
5. What is the impact if successful, and who would care?
6. How will you measure progress?
7. How much will it cost and how long will it take?

Similar criteria are used by each of the NIST programs to continually reevaluate ongoing projects in order to redirect funds as necessary. Further details on the questions that each proposal must address, and the criteria by which they are evaluated can be found in Appendix E.

Once a project has been selected for funding, it is evaluated regularly to ensure its effective operation and management. To accomplish this, NIST has implemented a thorough Performance Measurement and Evaluation System. Each major NIST program has a comprehensive performance measurement and evaluation system. The systems are designed to meet external requirements for measuring and reporting performance and provide valuable information for internal decision making and strategic planning. Additionally, NIST measures itself against numerous legislative requirements and government-wide initiatives. These include the Government Performance and Results Act; the President's Management Agenda; Program Assessment Rating Tool; and the Secretary's Policy Agenda of the Department of Commerce.

In addition to rigorous self-evaluation, NIST employs a variety of external, independent reviews and assessments to aid in its continuous improvement process. Examples include the Baldrige Process Improvement Panel, economic and other impact studies by independent contractors, and Federal Advisory Committee input for each major program.

Moreover, NIST long engaged the Academies' National Research Council (NRC) in conducting evaluations of each NIST laboratory program. The NRC performs a thorough evaluation of NIST programs and laboratories, a process that represents the cornerstone of NIST's evaluation system. The NRC Assessment Panels have reviewed the NIST laboratories since 1959. Through this expert peer-review process, NIST is provided with an assessment of technical quality, relevance, and effectiveness of each laboratory's programs. The Panel members are selected by the NRC from leaders in industry, academia, non-profit organizations, and government laboratories.

The final stage of the NIST evaluation system occurs after the completion of a program and entails a rigorous economic evaluation of the programs impacts. NIST has been a recognized leader in this field, conducting these economic impact studies on a regular basis since 1992 with the combined average of all 19 such studies yielding an average benefit-to-cost ratio of $44 for every $1 invested at NIST. These cover work ranging from NIST investments in providing a standard reference material to measure the sulfur content of fossil fuel emissions from factories and power plants to key data needed by the refrigeration and air-conditioning industry to respond to regulations governing chlorofluorocarbons and the accuracy of cholesterol in blood measurements. These studies evaluate the long-term impacts that derive from individual or, in some cases, a set of related projects within a single program. Over time, the projects cover a wide range of technologies and industries and provide quantitative estimates and qualitative assessments of the economic impact resulting from the various technology infrastructures. The benefits these studies illustrated are due to the fact that the scientific work done by NIST is highly infrastructural and contributes to the technological backbone so vital to innovation. In the past several years, NIST has not undertaken as many analyses as had been the case previously. Recognizing the importance of this input, NIST expects to undertake a greater number of impact analyses between FY 2009 and 2011.

8 REFERENCES

1. American Competitiveness Initiative, February 2006, http://www.whitehouse.gov/stateoftheunion/2006/aci/aci06-booklet.pdf
2. FY 2007 OSTP/OMB Budget Priorities Memoranda, http://www.whitehouse.gov/omb/memoranda/fy2007/m07-22.pdf
3. FY 2006 OSTP/OMB Budget Priorities Memoranda, http://www.whitehouse.gov/omb/memoranda/fy2006/m06-17.pdf
4. FY 2005 OSTP/OMB Budget Priorities Memoranda, http://www.whitehouse.gov/omb/memoranda/fy2005/m05-18.pdf
5. FY 2004 OSTP/OMB Budget Priorities Memoranda, http://www.whitehouse.gov/omb/memoranda/fy04/m04-23.pdf
6. FY 2003 OSTP/OMB Budget Priorities Memoranda, http://www.whitehouse.gov/omb/memoranda/m03-15.pdf
7. http://www.whitehouse.gov/omb/budintegration/pma_index.html
8. http://www.osec.doc.gov/bmi/budget/07strplan/DOC07strplan.pdf
9. Public law 107-252, Help America Vote Act of 2002
10. Public Law 110-69, August 9, 2007, 110th Congress [H.R. 2272]
11. Public Law 110-85 Sec. 305(c)(3), September 27, 2007 110th Congress [H.R. 3580]
12. http://www.nap.edu/catalog.php?record_id=11463
13. http://www.compete.org/

http://history.nasa.gov/spaceact.html
http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html
http://www.whitehouse.gov/omb/budintegration/pma_index.html
http://www.whitehouse.gov/omb/part/index.html

http://www.osec.doc.gov/bmi/budget/07strplan/DOC07strplan.pdf

9 Appendices

9.1 Appendix A: Detailed Description of Partially Funded and Pending NIST Budget Initiatives.

9.1.1 Strengthen Core Competencies

9.1.1.1 Innovations in Measurement Science

Challenge

Just as industry must innovate to survive in a competitive environment, NIST must continually develop innovative approaches to measurement challenges.

As new science and technology areas emerge, NIST must quickly develop the measurement methods needed to support them. The Innovations in Measurement Science Program is one of NIST's primary mechanisms for keeping pace with the measurement requirements needed for innovation in U.S. industry.

Established in 1979, the program supports high-risk, leading-edge research projects that anticipate industry needs and develop measurement science for the next generation of technology. At some point in their careers, all three of NIST's Nobel laureates have had their research funded by this program. Current NIST expertise in quantum information science, fuel cell science, three-dimensional chemical imaging, and many other areas important to national priorities were launched with "measurement innovations" funding.

Proposed NIST Program

This initiative will expand the scope and nature of projects selected for the Innovations in Measurement Science Program to allow this program to keep better pace with the evolving needs of industry and science. Emphasis will be placed on the development of multidisciplinary research areas with the greatest potential for fostering innovation.

The NIST Laboratories carefully evaluate the technical merit, potential impact, and staff qualifications for detailed research proposals submitted by the NIST technical staff. Only the strongest proposals survive this evaluation process. Successful proposals are funded for five years—ensuring enough time for the innovative measurement science approach to be developed—and are reviewed throughout the program to ensure satisfactory progress.

Expected Impacts

The expanded Innovations in Measurement Science Program will ensure that NIST can continue to anticipate the measurement science and standards needs of U.S. industry and science.

Specific outcomes include:

- new measurements and standards for advanced technology industries, including semiconductors, biotechnology, telecommunications, and information technology;
- state-of-the-art support for measurements in mature industry sectors such as the motor vehicle, heavy equipment, and aircraft industries;
- research and development in support of emerging and future industry measurement needs such as those found in nanotechnology.

9.1.1.2 Measurements and Standards to Accelerate Innovation in the Biosciences

Challenge

Inaccurate bioscience measurements sometimes make it hard to tell when treatments are healing or causing harm. They often increase costs and lower the quality of healthcare. The lack of reliable, quantitative measurements in the biosciences is also impeding progress in a number of promising life-science research areas.

Compared to the measurements made in the physical sciences, medical tests and bioscience-based measurements need to be repeated and rechecked far too frequently. Today, even standard measurements on a limited number of blood proteins often yield variable results among expert laboratories.

Meanwhile, bioscience measurement capabilities are still largely limited to studying only a few biological interactions at the same time, rather than the large numbers of molecules and many sophisticated interactions that are required to understand complex biological systems.

Proposed NIST Program

The research initiatives newly proposed in FY 2009 will focus on three intersecting areas of research:

- make biological data more quantitative and reliable by establishing methods, standards, and benchmark data for the fundamental measurements that underpin the life sciences in techniques such as mass spectrometry and molecular imaging;
- devise new methods for simultaneously measuring hundreds to thousands of molecules at a time by developing and validating new technologies in areas such as microfluidics and live cell imaging; and
- help laboratories more easily compare and combine their measurements and computer models with one another by developing standards for the exchange of biological data and information.

Expected Impacts

NIST research will provide physical science-based measurement tools to:

- reduce errors, reduce costs, and enable innovative measurement technologies;

- foster the development of "systems biology," the complex analysis of biological systems to provide a more detailed understanding of disease and drug design;
- decrease both the time and cost of drug development by having better measurements to identify problems with candidate drugs at earlier stages;
- pave the way to personalized medicine, through the existence of more detailed quantitative biological data; and
- improve prediction, diagnosis, management, and understanding of disease through the use and exchange of standardized data.

9.1.1.3 Nanotechnology: Environment, Health and Safety Measurements & Standards Challenge

Products made with nanometer-scale components and materials—a thousand times thinner than a human hair and smaller—are already dramatically improving the performance of current products from stain-resistant pants to fuel-efficient aircraft. Many more applications beckon such as targeted cancer drugs, ultrafast electronics, and improved diagnostic tools for medicine.

The small size of these components produces new properties not seen in larger-scale "bulk" materials. While nanomaterials promise many useful applications, very little is known about the environmental, health, and safety (EHS) risks associated with them. The safety or toxicity of nanomaterials can be determined only with well-understood materials and well-defined testing methods.

The bottom line is that hundreds of products already contain nanoscale components and materials and the safety of these products is unknown. As a result, industry is increasingly concerned about future potential liability issues. Regulatory agencies lack the basic scientific information they need to protect the public. In light of these concerns, the scientific community fears that the next breakthrough in nanotechnology may be smothered by uncertainty before it has a chance to be born.

Proposed NIST Program

The interagency National Nanotechnology Initiative has designated NIST as the lead federal agency to develop metrology tools and methods for measuring and characterizing nanomaterials. NIST has the interdisciplinary physical-science expertise and the facilities needed to develop accurate, validated methods for understanding the EHS properties of nanoscale materials.

Initiative funding will allow NIST to launch a three-pronged approach to the problem:

- create a classification scheme for determining the characteristics of nanoparticles necessary for assessing toxicity, including size, shape, and chemical composition;
- develop detection and measurement methods for quantifying the number and nature of nanoparticles with EHS impact in biological and environmental samples; and

- predict how modifications to nanoparticles will affect their impact on the environment, health, and safety.

Expected Impacts

NIST work in this area will allow:

- industry to accurately measure the quantities, types, and potential EHS risks of nanomaterials and manufactured products containing them;
- other government agencies to develop appropriate regulations to protect against potential EHS effects of nanomaterials based on reliable data and solid science;
- consumers to confidently buy products using nanomaterials knowing that the EHS effects have been accurately assessed; and
- accelerated industrial innovation that safely exploits the promise of nanotechnology by reducing uncertainty and quickly identifying any potential hazards before they harm workers or the public.

9.1.2 Addressing Rapidly Developing Technology

9.1.2.1 Going at Light Speed: Optical Communications and Computing

Challenge

As demand on the U.S. communications network continues to grow, a new generation of transmission and networking technologies is required to keep pace. Keeping pace is critical because communications fundamentally drives productivity gains and economic growth; it cradles innovation in many current and future industries, including telemedicine, entertainment, and security.

To meet these needs, data rates will approach 100 gigabits per second and beyond, but measurements at these bandwidths are lacking. Improvements to the network are required to provide the capacity needed for universal broadband access in our nation. Networks will have to become more agile, so that operators can better utilize capacity and address changing demands. Currently, few measurement tools exist to monitor the real-time performance of transmission links, making it slow and costly to re-route, or reconfigure, data traffic in a network.

Industry currently lacks the optical measurement capabilities essential to take full advantage of the existing U.S. communications infrastructure and enable next-generation data-transmission technologies. These measurement capabilities are crucial for developing faster fiber-optic data rates and more flexible data-transmission systems and for enabling faster communications within the computers that connect to the information highway.

Proposed NIST Program

This initiative will promote advances in light-scale communications ranging from the nanoscopic innards of an individual computer to the continent-spanning scale of the nation’s optical communications network. Already the world leader in measurements of high-speed devices and of hybrid optical and electronic devices, NIST will work closely with industry and expand its work to include research and development of:

- new measurement capabilities to accommodate higher-speed, next-generation communications networks;
- measurements that diagnose and locate transmission problems on data networks, and provide the information needed to reconfigure and redirect traffic to match demand; and
- new measurement techniques for analyzing computer circuits that transmit light instead of electricity, enabling the manipulation of light within computer chips, and interconnecting very small electronic and optical devices.

Expected Impacts

NIST work in this area should help to:

- maintain and increase the competitiveness of U.S. communications and information technology industries by providing new capabilities for optical measurements on existing and new infrastructure;
- lower costs for operating and maintaining communications networks by providing improved functionality of optical communications equipment and creating tools for making networks more robust; and
- increase speeds for individual computer users by supporting the development of higher speed, lower-power computers that use light rather than electricity to process information.

9.1.2.2 Enabling Nanotechnology from Discovery to Manufacture

Challenge

With production using nanoscale components and processes soon expected to become a dominant factor, the United States faces dramatic changes in manufacturing in the 21st century. The promise of U.S. investment and innovation in nanotechnology can be realized only if the necessary infrastructure of measurement methods and standards is available to produce superior nanotechnology products.

Products built from nanoscale components—a thousand times thinner than a human hair—require entirely new ways to accurately quantify their properties and determine their sizes, shapes, and chemical composition.

Proposed NIST Program

In FY 2007, NIST began a major initiative to address the measurement barriers hindering rapid development of nanotechnologies. A new NIST Center for Nanoscale Science and Technology (CNST) has been established that combines both research and a state-of-the-art nanofabrication and nanometrology user facility.

While a complementary NIST initiative will provide important groundwork in measuring environmental, health, and safety (EHS) risks of nanotechnology, this research initiative will build on recent NIST advances in developing nanoscale science and technology by:

- devising ways to measure strength, stress, strain, optical, and electronic properties of nanostructures to improve processes and understanding of failure mechanisms;
- creating three-dimensional, high-resolution imaging methods that reveal details of structure, chemical composition, and manufacturing defects and allow researchers to view nanostructures as they interact with their environment;
- simulating nanoscale phenomena with computer models to allow economical development of production methods for complex nanodevices; and
- pushing existing computer technology to its ultimate limit by developing measurements and standards that support "ultimate CMOS," or the development of current transistor technology to its technological limit.

Expected Impacts

NIST work in this area should help to:

- enhance the global competitiveness of U.S. manufacturers whose products incorporate nanotechnology;
- accelerate private-sector commercialization of new products and innovations such as high-strength, high-toughness materials for greater auto fuel efficiency and personal protection, as well as drug delivery systems with nanoscale components;
- enable more compact, powerful, and innovative products made with nanotechnology-enhanced electronic chips that are smaller, faster, and more efficient; and
- produce increased yield, productivity, and reliability in the manufacture of nanostructures and devices for the electronics, sensor, information storage, and communications industries.

9.1.2.3 Enabling the Use of Hydrogen as a Fuel

Challenge

Hydrogen offers the possibility of lowering the impact of motor vehicles on the environment, and reducing our nation's dependence on foreign oil.

While the burning of fossil fuels produces carbon dioxide and other emissions harmful to the environment, hydrogen fuel can be made from many energy sources, including renewables. Automakers are beginning to offer consumers early-version hydrogen-powered vehicles in certain areas of the United States.

Technical challenges need to be overcome to make hydrogen-powered vehicles more practical and economical. Hydrogen can embrittle metals and other container materials, is highly combustible, and requires storage containers larger than those for other fuels with equivalent energy. Moreover, the technical infrastructure must be developed to ensure safe production, storage, distribution, delivery, and equitable sale of hydrogen in the marketplace. Fuel cells for powering the vehicle must be improved to operate reliably for 5,000 hours under ordinary driving conditions in all regions of the country.

Proposed NIST Program

Expansion of research efforts at NIST is essential to achieving widespread use of hydrogen as a fuel. NIST has been a leading provider of data on the chemical and physical properties of hydrogen for more than 50 years. It has statutory responsibility under the Pipeline Safety Act of 2002 to develop research and standards for gas pipeline integrity, safety, and reliability. It is the lead U.S. agency for weights and measures of vehicle fuels, and the distribution and sale of hydrogen will require entirely new systems for ensuring equity in the marketplace.

NIST's Center for Neutron Research is a premier facility for real-time, three-dimensional imaging of hydrogen in operating fuel cells. Using the unique resources developed at this NIST facility will help reduce technical barriers for efficient hydrogen production, storage, and use.

NIST expertise will be essential for making fuel cells less costly and more reliable. Initiative outcomes will include, for example, development of physical measurement (reference) standards and calibration services for hydrogen flow rate and purity, research on appropriate fuel cell performance-based testing and rating procedures, development of fire hazard predictive models, and evaluation of fire suppression systems.

Expected Impacts

The NIST efforts will help realize the promise of making hydrogen-powered vehicles more economical by:

- fostering private-sector innovation of more powerful, efficient, and durable fuel-cell designs;
- ensuring accurate measures of hydrogen at points of sale;
- producing consensus standards that support model building codes for such facilities as filling stations;
- facilitating the adoption of hydrogen technologies in local communities; and
- improving industrial safety standards for materials used in hydrogen systems (e.g., pipelines) developed in collaboration with consensus standards organizations.

9.1.3 Expanding Frontiers of Measurement Science

9.1.3.1 Quantum Information Science/Enabling Innovation through Quantum Science Challenge

The laws of physics are fundamentally different in the quantum world of atoms, electrons, and photons (light particles) than in our everyday macroscopic world. Exploring and harnessing the special properties of the quantum realm hold promise for new and powerful technologies fundamentally different from many conventional technologies of today.

NIST scientists are world leaders in the emerging field of quantum science. Three NIST scientists have won separate Nobel Prizes in the last 10 years based on their work in the field. Many of the best minds in physics today believe that applications of quantum science will transform the 21st century just as integrated circuits and classical electronics transformed the 20th century.

Proposed NIST Program

Having developed potential components for quantum computers and demonstrated other advances, NIST is proposing to expand further its quantum science program in FY 2009. Several of the projects proposed under this initiative will be in collaboration with the Joint Quantum Institute established by NIST, the University of Maryland, and the National Security Agency. NIST will:

- begin development of quantum "wires" that use "teleportation" techniques to reliably transport information between the components of a simple quantum computer based on manipulation of atoms, other elementary particles, or solid-state quantum devices;
- begin development of quantum memory analogous to the random access memory of today's computers to allow more complex logic operations;
- begin development of methods for transferring quantum-based information from one form (such as atoms) to another form (such as photons);
- develop an all-optical clock for more precise time and frequency measurement; and
- exploit the unusual quantum properties of "coherence" and entanglement to provide exquisite physical science measurement capabilities with improved sensitivity, accuracy, and speed.

Expected Impacts

Successful achievement of NIST goals in quantum science is expected to pave the way for:

- development of powerful quantum computers capable of solving certain types of complex problems that are impossible or prohibitively costly to solve with today's technologies;
- "unbreakable" encryption of electronic communications to enhance security of national security, financial, and market transactions; and
- quantum logic clocks capable of providing improved time and frequency for the next generation of the Global Positioning System (GPS) and for tests of fundamental physics theories.

9.1.3.2 NIST Center for Neutron Research (NCNR) Expansion and Reliability Improvements: A National Need

Challenge

Neutron beams have become an indispensable research tool in materials science, biotechnology, chemistry, engineering, and physics because of their ability to image materials and structures nondestructively at atomic and molecular scales. As a measurement probe, neutrons have unique advantages over other nanoscale techniques such as X-rays. The unique sensitivity of neutrons to magnetism and hydrogen is harnessed to study materials that push the frontier of modern technological capability, including advanced superconductors, spin-based electronics, protein function, hydrogen fuel cells, and hydrogen storage materials.

Serving more scientists and engineers (over 2,000 annually) than all other U.S. neutron research facilities combined, the NIST Center for Neutron Research (NCNR) is the nation's leading neutron facility. The NCNR is especially valued for its "cold" (low-energy) neutron source, which greatly increases the utility of the neutron beam, particularly in biotech and materials research.

Although the NCNR is widely regarded as the most cost-effective and efficiently managed neutron facility in the United States, presently this critical research tool cannot possibly meet the demands placed on it.

Proposed NIST Program

This is a planned increase in funding for the NCNR Expansion Initiative, begun in 2007. When completed, this five-year project will provide:

- a new generation of world-class cold neutron instruments directly supporting the needs of science and industry;
- more than a 25 percent increase in the overall measurement capacity;
- the ability to serve at least 500 additional researchers each year; and
- increased operational efficiency.

The FY 2009 funding request supports the next phase of the NCNR expansion to initiate installation, testing, and commissioning of the new neutron instruments (such as spectrometers). These instruments will bring new neutron measurement capability to U.S. researchers by either exceeding the capabilities of current instruments by more than a factor of a hundred, or by providing capabilities that are not currently available in the United States.

In FY 2009, the project will focus on:

- installation of new neutron spectrometers and neutron beamlines;
- modification of beamlines and beamline shielding;
- modification of some existing instruments affected by new beamlines; and
- testing of new beamlines and instruments.

Expected Impacts

Completion of the NCNR expansion will allow:

- a new generation of world-class instruments directly supporting the needs of science and industry;
- an increase in the overall measurement capacity of the NCNR by more than 25 percent;
- the ability to serve at least 500 additional researchers each year; and
- increased operational effectiveness.

9.1.3.3 JILA Expansion: Preparing the Next Generation of Physicists

Challenge

Space has run out at one of the nation's most valuable training grounds of top scientific talent. JILA, a joint institute of NIST and the University of Colorado at Boulder, has produced three Nobel Laureates and two MacArthur Fellows, all named in this decade alone. JILA researchers are leaders in atomic, molecular, and optical (AMO) science, a field that the National Academies says is "key to training our best scientists, engineers, and technical professionals."

In the last 13 years, JILA scientists have created two new types of matter. One may hold the secrets to superconductivity, which could lead to dramatically more efficient electrical power transmission. State-of-the-art devices for manipulating atoms, molecules, and light created by JILA scientists promise a cascade of new capabilities in biotechnology and healthcare, nanotechnology, energy, homeland security, and many other areas.

JILA is already over capacity, and the situation is getting worse. The existing group of 28 JILA research scientists could train approximately one-third more postdocs and student researchers, but there is literally no place for them to work. Current laboratory space is so cramped that safety concerns may begin affecting the lab's operations. JILA also needs specialized laboratory space such as cold rooms for biophysics research and clean rooms to support research in nanometer-scale electronics. An expert external assessment of the JILA laboratories warned that this shortage of space threatened JILA's ability to retain and recruit world-class scientists.

Proposed NIST Program

NIST proposes a limited expansion of the laboratory and office space at JILA. With the expansion costing an estimated $27.5 million, NIST would contribute $13 million in FY 2009 and an additional $9.5 million in FY 2010. The University of Colorado will contribute $5 million in funding, as well as land and infrastructure services such as electricity, chilled water, and steam.

The funding would add approximately 4,610 square meters (49,600 square feet) of new space. Improving the laboratory facilities at JILA will ensure that the current world-class research staff maximizes its potential for both training a new generation of scientists and producing the nanoscale manipulation tools needed to keep U.S. industry at the forefront of science. The expansion is expected to increase the number of AMO grad students at JILA by approximately 50 percent. Because JILA produces 5 to 10 percent of all AMO science Ph.D.s in the United States per year, this will step up significantly the nation's production of scientists in this important field.

Expected Impacts

Expanding JILA will produce outcomes directly aligned with the goals of the American Competitiveness Initiative, such as:

- maintaining our nation's lead in science, by developing ultrastable atomic clocks, precision laser measurement tools, and new methods for probing the properties of ultracold matter;
- increasing the nation's capacity to train top scientists, many of whom traditionally go on to work in government, industry, and academia; and
- delivering innovations in technologies from lasers to airport security detectors that will improve our competitiveness and quality of life.

9.1.3.4 Building 1 Extension (B1E) – Enabling Sustained Scientific Advancement and Innovation

Challenge

When President Eisenhower dedicated the NIST facilities in Boulder, Colo., in 1954, no one imagined that half a century later scientists would be manipulating matter atom by atom. Such technological advances require increasingly complex and difficult measurements to be able to observe, characterize, and create structures at ever smaller spatial scales.

As the structures shrink in size, small fluctuations in temperature, humidity, air quality, and vibration begin to distort the results. These conditions are inhibiting further advances in some of the most promising areas of research for the 21st century.

As the nation's premier measurement agency, NIST must be able to produce extremely accurate data for industry and academia to maintain confidence in its results. Improvement in environmental conditions within NIST's Boulder, Colo., research laboratories is required to make further progress in measurements related to high-frequency electronics, advanced materials characterized at the atomic level, subcellular forces, timing accuracy, and other areas.

Proposed NIST Program

As the final funding request for a three-year program, the $43.5 million proposed in the FY 2009 budget will complete state-of-the-art laboratory space that will meet the stringent environmental conditions required for 21st-century scientific advances. With a total cost of $77.2 million, the Building 1 Extension is the most cost-effective approach to enabling world-class measurement science in support of some of the country's most important economic sectors.

Expected Impacts

Construction of the B1E will dramatically enhance NIST's measurement capability and will directly support the needs of industry and academia. Some of the anticipated impacts include the ability to:

- make precision frequency measurements above 100 GHz (100 billion cycles per second), which are required for advanced commercial electronics, military systems, and homeland security;
- measure and perform research on the properties of materials at the single-atom level needed for the development of quantum and nanotechnologies;
- measure forces below 10^{-12} newtons (one billionth the weight of a feather) to understand the inner workings of cells and to apply this measurement capability to other physical systems; and
- make timing measurements with uncertainties reduced to one part in 10^{-18} (the equivalent of one second in 30 billion years), enabling whole new generations of position, navigation, and guidance systems.

9.1.4 Meeting Critical National Needs

9.1.4.1 National Earthquake Hazards Reduction Program

Challenge

Earthquakes strike without warning. Within the United States, more than 75 million people are located in urban areas considered to be at moderate to high risk for earthquakes. Just the economic value of the physical structures within these regions—not including the potential loss of life and economic disruption—is valued at close to $8.6 trillion. A single large earthquake in the United States, like the one that struck Kobe, Japan, in 1995, can easily cause damage of $100 billion to $200 billion.

A critical gap exists between the results produced by basic research and the implementation of that knowledge in the field. New construction materials, techniques, building codes, and standards do not reflect the current state of knowledge. Through the National Earthquake Hazards Reduction Program (NEHRP), NIST is tasked with conducting problem-focused research to bridge this gap and to promote its application by the private sector.

In addition to enhancing the resiliency of new structures, it is important to establish accurate evaluation techniques for assessing the robustness of existing buildings and to develop cost-effective rehabilitation techniques for those structures that are most vulnerable to collapse or major damage. According to a 2003 National Research Council study, "Perhaps the greatest overall risk in the United States is the severe earthquake damage (including collapse) to existing facilities and lifelines designed without consideration of earthquake effects."

Proposed NIST Program

At the proposed funding level, NIST will:

- identify implementation gaps between basic research results and design guidance and national model building code provisions;
- develop rational cost-effective, consensus-based seismic design and analysis procedures for use in national model building codes;
- design guidelines for the testing and design of major structural systems;
- characterize fully the seismic capacities of typical older building structural components and systems as they are built; and
- develop structural performance criteria, analytical models, and cost-effective rehabilitation techniques for existing buildings.

Expected Impacts

Results expected from the research conducted through this initiative include:

- updated model building codes and standards that incorporate the latest scientific research aimed at reducing the risk to life and property from earthquakes;
- application of the products of basic research related to earthquake effects on buildings and infrastructure into cost-effective tools for evaluating new and existing buildings; and
- technical resources such as guidelines, manuals, and mitigation technologies to enhance U.S. structural engineering practices and improve U.S. economic competitiveness in national and international construction markets.

9.1.4.2 Measurements and Standards for Climate Change Science Program

Challenge

The climate is changing. Determining how fast it is changing and understanding the complex relationship between all the environmental variables to allow accurate predictions is part of the objective of the U.S. Climate Change Science Program. Some of the drivers of climate, such as the sun's output, may vary slowly over decades. As a result, climate predictions depend critically on developing absolute measurements of the sun's energy that can be compared accurately over decades from different sensors. Other important variables include the sizes, shapes, and chemical composition of particles or droplets (aerosols) in the atmosphere. Whether aerosols contribute to the warming or the cooling of the Earth depends upon their composition.

Many different climate monitoring systems in space, in the air, and on the ground are currently monitoring solar output as well as trapping and reflection of heat by the Earth's atmosphere. These systems are operated by multiple countries and research groups. The reliability of the resulting information can be—and is—affected by the various measurement techniques and databases used. Establishment of absolute calibration and standard references will allow accurate comparisons of these systems, will help identify small environmental changes occurring over many years, and will reduce uncertainties in the data input to global climate change models.

Proposed NIST Program

With the funding provided through this initiative and in coordination with other agencies, NIST will develop:

- an international irradiance measurement scale to be used in rigorously calibrating satellite light intensity instruments prior to launch to ensure sufficient accuracy to allow valid comparisons among results from different instruments or from data sets taken over different periods of time;
- new instrument design strategies and quality assurance programs to optimize accuracy and stability of satellite and ground-based solar measurement systems;
- techniques for generating specific types of aerosols in the laboratory, measuring aerosol optical and physical properties, and simulating aerosol properties that cannot yet be measured in the laboratory; and
- a database of critically evaluated data on aerosol properties collected at NIST and elsewhere.

Expected Impacts

This initiative will fill two critical gaps in data needed for accurate climate modeling:

- enabling the accurate determination of the total amount of sunlight reaching the Earth over specific periods of time; and
- measuring the properties and behavior of aerosols in the atmosphere that impact global climate.

Data collected through these efforts will improve the accuracy of climate change predictions and provide policymakers with better information about the impact of various policy options.

9.1.4.3 Disaster Resilient Structures and Communities

Challenge

For the past few years, natural hazards, including hurricanes, extreme winds, storm surge, wildland fires, earthquakes, and tsunamis, as well as terrorist actions, have been a continuing and significant threat to U.S. communities.

The disaster resilience of our physical infrastructure and communities today is determined in large measure by the building standards, codes, and practices used when they were built. With few exceptions, these are oversimplified and inconsistent with current risk assessments. As construction and rebuilding costs continue to rise, there is increasing recognition of the need to move from response and recovery to proactively identifying and mitigating hazards that pose the greatest threats.

Proposed NIST Program

NIST and the National Oceanic and Atmospheric Administration (NOAA) have coordinated their programs in this area. Initiative funding in FY 2009 will allow NIST to develop:

- standard methods to predict losses, evaluate disaster resilience, and estimate cost-to-benefit of risk management strategies at the community and regional scales as opposed to the individual building scale;
- decision support tools to modernize standards, codes, and practices consistent with the risk;
- a validated "computational wind tunnel" for predicting extreme wind effects on structures; and
- risk-based storm surge maps to be used in designing structures in coastal regions and an improved hurricane intensity classification scale.

In addition, the funding will allow expansion and acceleration of research results for projects begun with funding in FY 2007 on:

- prediction of fire hazards at the wildland/urban interface; and
- improved tools for designing and constructing earthquake-resistant structures.

Expected Impacts

A 2005 National Institute of Building Sciences study found that a dollar spent on hazard mitigation saves society an average of $4, with positive benefit-cost ratios for all hazard types studied. This initiative will improve community resiliency and protect property and lives through:

- reduced risk from hurricanes and windstorms, fires at the wildland/urban interface, and earthquakes;
- science-based tools for more robust hazard mitigation assessments, better local and private resource allocation decisions, and guidance to communities for responding to large-scale wildland/urban fires;
- both short- and long-term improvement in seismic, wind, and fire provisions for model building codes; and
- technical resources such as guidelines, manuals, and evaluation of mitigation technologies that enhance structural engineering practice.

9.1.4.4 Comprehensive National Cyber Security Initiative: Leap-Ahead Security Technologies

Challenge

This NIST request is part of the Administration's Comprehensive Cyber Security Initiative. From online shopping to telecommuting, our society and economy have become increasingly reliant on interconnected computer networks. To help foster continued economic growth, improving the security of networked computer systems must be a national priority.

Many of today's tools and mechanisms for protecting against cyber attacks were designed with yesterday's technology in mind. Information systems have evolved from room-size computer workstations shut off from the rest of the world to ubiquitous mobile devices interconnected by a global Internet. In this diverse ecology of communication devices, no cyber security solution works on all operating systems and can protect every type of computer and network component. Operating systems are now composed of millions of lines of code, rather than thousands, and have many more potential holes.

Attackers must find only one hole in a security system for success while security experts must close all potential vulnerabilities of the system.

Proposed NIST Program

NIST is a recognized world leader in the field of cyber security. Working with other federal agencies, NIST proposes an initiative in three essential elements of cyber security infrastructure:

- create technical standards for generating, distributing, using, storing and destroying secret numbers known as cryptographic keys, commonly used to grant access to authorized individuals on encrypted computer networks and systems. This effort will be conducted in technical consultation with the National Security Agency (NSA) and the Department of Defense (DoD), as well as other government agencies and non-government organizations;
- nurture the development of "multifactor authentication" methods. Such methods require users to verify their identities through multiple methods, such as passwords and iris scans, rather than just one. NIST will develop a standardized framework that ensures these methods work across different computer platforms and operating systems. The effort will be coordinated with vendors and federal departments, including the Department of Homeland Security; and
- extend the Federal Desktop Core Configuration, a set of standard security settings that optimize security, to other operating systems, applications, and network devices beyond the existing support for Windows XP and Vista.

Expected Impacts

This work will help to:

- increase the security of U.S. communications, information, and critical infrastructure;
- safeguard the confidentiality and integrity of information through the further development of cryptographic keys;
- improve the interoperability of systems for authenticating individuals and machines on networks;
- help organizations establish compliance with IT security requirements by standardizing security settings for a wide range of computers, operating systems, and applications;
- lower the economic impact from identity theft; and

- increase the productivity of electronic commerce by providing reliable automated systems that protect the confidentiality and integrity of information being exchanged.

9.1.4.5 Biometrics: Identifying Friend or Foe

Challenge

Hundreds of millions of people enter the United States every year at the nation's borders and other points of entry. To protect the country against terrorists and other threats, it is vital that known or suspected terrorists and people with terrorist ties be intercepted before they enter the country. It also is important that these security efforts ensure a speedy and smooth flow of international visitors at entry checkpoints. Accurate, reliable biometric technologies—automated tools that identify people based on physical or behavioral characteristics—are crucial to achieving both of these objectives.

NIST has decades of experience improving human identification systems and currently is working with other federal agencies, including the Department of Homeland Security, the Federal Bureau of Investigation, and the U.S. Department of State, to evaluate and improve the ability of biometrics to enhance border security. The USA Patriot Act and the Enhanced Border Security and Visa Entry Reform Act call for NIST to develop and certify a technology standard for verifying the identity of individuals and to determine the accuracy of biometric technologies, including fingerprint, facial, and iris recognition.

Biometrics technologies, primarily fingerprints, are being used broadly in the United States for border security. New technologies under development, in particular, "multimodal" systems that combine two or more biometric technologies, such as fingerprint, facial, and iris, promise to bring significant improvements. But NIST studies have shown that the accuracy of today's facial recognition systems is relatively poor compared to fingerprints, and iris recognition needs more study and testing to determine its accuracy in operational environments.

In conjunction with several other federal agencies, including the FBI and Department of Homeland Security, private industry and universities, NIST is managing the Multiple Biometric Grand Challenge, which aims to reduce errors in both face and iris recognition systems. Also, NIST is performing large-scale evaluations of iris recognition to promote its standardization.

NIST is also supporting the development of standards for interoperability between different fingerprint systems through large-scale testing.

Proposed NIST Program

With additional funding, NIST will:

- enable facial recognition technologies to be used for border security;
- build on its testing program to determine the accuracy of multimodal systems;

- develop tests and guidelines to assure that future biometric systems are interoperable, and work efficiently in real-time applications by:
    - improving the use of fingerprints with real-time fingerprint readers;
    - improve the interoperability, robustness, and usability of fingerprint systems and facial recognition systems;
- improve biometric systems by enabling simultaneous use of facial recognition, fingerprint, and iris-scan technologies.

NIST will coordinate this work with other government agencies and the private sector while taking international standards developments into account.

Expected Impacts

This effort will smooth the flow of international travelers at border checkpoints by increasing the accuracy as well as the efficiency, speed, and usability of biometrics for border security.

9.1.4.6 Manufacturing Innovation through Supply Chain Integration

Challenge

Everyone has experienced the occasional headache in sharing or moving data from one computer to another, but in the nation's manufacturing and construction industries, it is a multi-billion-dollar problem. America's large manufacturers are globally distributed enterprises that rely on a system of small manufacturers, parts suppliers, shippers, and raw materials producers organized in extended "supply chains." The U.S. construction industry is made up of an equally diverse network of more than 1 million firms. Using the auto industry as an example, the average car has more than 15,000 parts coming from 5,000 manufacturers that are made to the precise specifications of the auto company and must arrive on time.

Production costs are no longer the major cost component in these global supply chains—the dominant cost is in the engineering and business activities, which depend critically upon clear and error-free exchange of information among partners.

Inefficiencies and needless roadblocks in the exchange of product design and business data in manufacturing and construction are estimated to cost the U.S. economy more than $25 billion per year. Small manufacturers are particularly hurt by these problems, but they affect the competitiveness of entire industries.

Proposed NIST Program

In the 1980s NIST pioneered work in developing early open standards for data exchange. Under this initiative, NIST will conduct a much more extensive, wide-ranging, and technologically advanced program. Working closely with U.S. manufacturers to develop seamless data transactions throughout global supply chains, NIST will work to shorten the design-to-manufacturing cycle, improve quality, and lower costs for large and small U.S. firms.

Major goals will include:

- creating "roadmaps" for the development of open standards for enterprise integration in target industry sectors;
- developing validation and conformance tests to help ensure the performance of these standards as well as their proper use; and
- ensuring the standards are integrated and consistent with developing international standards and easily available to small and medium-sized U.S. manufacturers.

Expected Impacts

A robust, widely accepted framework of standards for enterprise integration will help open the global marketplace to the nation's small manufacturers.
Other potential benefits include:

- savings of approximately $1 billion in enterprise integration costs for U.S. manufacturers and producers in target industries (initially automotive and construction);
- a 20 percent reduction in "time-to-market" for manufacturers and producers in target industries;
- a 50 percent reduction in information technology costs for small and medium-sized manufacturers in target industries; and
- spillover benefits to other manufacturing industries, including electronics, medical devices, jet engines and aerospace, shipbuilding, chemicals, and specialty textiles.

9.2 Appendix B: NIST Funding Allocations for High-Risk, High-Reward Research

Section 1008 of the America COMPETES Act states that it is the intent of the Congress to support and promote innovation in the U.S. through high-risk, high-reward basic research projects. The Act requires that each Executive agency shall submit a report describing whether a target percentage of funding has been set for this type of research and "*if such a goal has been established, the following:*
(1) A description of such funding goal.
(2) Whether such funding goal is being met by the agency.
(3) A description of activities supported by amounts allocated in accordance with such funding goal."

High-Risk Basic Research: The Foundation of NIST's Success

The National Institute of Standards and Technology (NIST) is the premier Federal laboratory supporting the measurements and standards requirements of the nation. As an agency of the Department of Commerce, the research efforts at NIST are targeted at providing the technological measurement infrastructure that enables innovation and supports industrial competitiveness. Specifically, the mission of NIST is:

> *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.*

Unlike most other Federal science agencies, where the mission is focused around specific scientific and technological areas (e.g. space, health, agriculture, etc.) NIST's mission requires an extremely broad range of deep expertise. Research and development projects conducted by the NIST laboratories have direct application in many science and technology sectors – from engineering applications relating to computers, communications, and building research to cutting edge basic research into quantum computing, protein biomarkers, Bose-Einstein condensates, and nanomaterials. As such, NIST maintains research programs and expertise in a broad range of scientific and engineering disciplines. High-risk research in these disciplines helps NIST prepare for the next generation of technologies and their related measurement and standards challenges.

The conduct of high-risk basic research places NIST at the forefront of scientific and technological achievement. It enables the creation of the measurement and standards infrastructure that provides a bridge from the basic sciences to industrial applications. Whether it is research in optics for highly accurate clocks that enable Global Positioning Systems or work on the design and characterization of nanomaterials that enable the safe and responsible exploitation of nanotechnology, NIST is committed to conducting high-risk basic research.

A number of mechanisms are used to support high-risk research at NIST. These include internal competitions to promote new research areas, focused programs in key technology areas, and joint collaborations with leading research institutions. Although NIST has not set a formal goal for the funding of high-risk basic research, NIST will invest approximately 12 percent of our R&D budget on high-risk research in FY 2008 – a level that has been fairly consistent through the years. Increases requested in the President's FY2009 budget would increase NIST's support for high-risk research to 17.8 percent of NIST's research budget.[1]

Mechanisms for the Support of NIST High-risk Basic Research:

At NIST, there are a variety of mechanisms that NIST management utilizes to continually foster and promote high-risk research. Examples include:

The Innovations in Measurement Science Program: The Innovations in Measurement Science (IMS) Program provides funds to explore high-risk, leading-edge research concepts that anticipate future measurement and standards needs of industry and science. These funds are a principal mechanism for initiating the new programs and research directions necessary for NIST to keep pace with and respond quickly to the increasingly complex nature, and the shorter time frame, of technology development.

Since its inception in 1979, the IMS Program has: 1) funded over 100 research projects that have evolved into core activities within the NIST Laboratories; 2) formed the cutting edge of NIST's research programs; and 3) attracted some of the Nation's top scientific talent to NIST. Three NIST Nobel Prize winners in Physics (Dr. William Phillips, 1997; Dr. Eric Cornell, 2001; and Dr. Jan Hall, 2005) each had projects that were funded partially by the IMS Program. Other program achievements include the development of a cold-neutron small-angle scattering facility, a bold concept that ultimately led to the NIST Center for Neutron Research (NCNR), now a premier research program that attracts more than 2,000 affiliated researchers annually from industry, government, and academia. As these examples demonstrate, the IMS Program provides the framework for the development of new ideas and the research needed to test their viability. The program continually revitalizes NIST and its staff, and helps ensure that the agency can quickly respond to industry needs.

JILA: This world-class research organization is a joint institute of the University of Colorado and NIST. JILA's experts in atomic, molecular and optical (AMO) science are widely recognized as international leaders in their field. Two of NIST's three Nobel Laureates conduct their research at JILA. In addition, Deborah Jin, a NIST/JILA scientist working in this area recently won a MacArthur Fellows Grant.

JILA scientists develop scientific tools that improve the productivity of all scientists and produce radical innovations that impact nearly every sector of the economy. AMO

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[1] While the research supported by TIP is defined as high-risk it has not been included in these calculations as the funding of projects has not yet begun.

scientists investigate the building blocks of matter in the universe, studying the properties of the fundamental forces of nature at the subatomic scale. Research by JILA's scientists has made it possible to conduct revolutionary experiments and make observations that have resulted in extraordinary discoveries and led to new understandings of the universe. These fundamental breakthroughs in AMO science and amazing new scientific tools facilitate discovery throughout the scientific world and push the frontiers of technology in ways that impact Americans' quality of life and our national competitiveness.

For example, in the 1930s AMO scientists developed techniques to measure the magnetic properties of subatomic particles. The tools and fundamental knowledge that these scientists generated led to magnetic resonance spectroscopy in the 1940s, magnetic imaging of the human body in the 1970s, and state-of-the-art MRI breast cancer screening today. Similarly, in 1954 the development of the precursor to lasers represented a fundamental breakthrough in molecular science. This discovery led directly to the development of the lasers, which today have important applications in nearly every facet of the economy ranging from manufacturing, healthcare, consumer electronics, and national defense. Today, work at JILA is making major contributions to the field of AMO physics. JILA is a leader in research related to ultracold matter and the control of atoms and molecules with ultrafast lasers. The institute is world renowned for its work in Bose-Einstein and fermionic condensation and the development of ultrafast lasers capable of manipulating matter at room temperature. The results of the work at JILA today will impact our understanding of the universe and the development of future technologies for years to come.

Quantum Information Science Research Program: Since the early 20th century we have known that the microscopic, or quantum, realm works under vastly different rules than the world of our everyday experience. The ability to understand and exploit many aspects of the quantum realm led to many of the technological advances that defined the last century. Yet the quantum realm holds still more surprises and more possibilities. The special quantum properties of coherence and entanglement have no counterparts in our everyday world and have been the most difficult aspects of the quantum world to understand, but these are also the quantum behaviors that hold greatest promise for development of new technologies. In simple terms quantum coherence can be described as the ability of atoms, light particles, or other quantum objects to simultaneously possess two mutually exclusive states at once – to spin both clockwise and counterclockwise, for example. Entanglement, which Albert Einstein called "spooky action at a distance" occurs when the quantum properties of one particle are correlated with the properties of another instantaneously even when they are physically separated.

It has only been in recent years that scientists have been able to create and control quantum coherence and entanglement in the laboratory. These new techniques open the door to new possibilities with broad societal impact. Many of the greatest physicists believe that exploitation of these non-intuitive properties of nature will transform the technology of the 21st century, just as electronics transformed the technology of the 20th. However, there is a very high risk associated with this research, and the private sector tends to avoid such risky ventures; therefore, this is a research area where federal funding is exceptionally useful.

Researchers at NIST have been at the forefront of demonstrating that quantum coherence and entanglement can be created and controlled in the laboratory. These advances promise to allow fantastic new capabilities, such as quantum computing with vastly superior power compared to today's classical computers and quantum communication with unbreakable security. NIST scientists were the first to demonstrate a quantum logic operation with a quantum "bit" or "qubit" and among the first to demonstrate the principle of quantum communication. These early advances prompted NIST to begin a focused program in Quantum Information Science. That program is now the largest internal quantum research program in the Federal government and one of the most successful programs in the world. Now NIST scientists are hoping to push still further ahead. The ultimate goal for the NIST program is to parlay early proof-of-principle demonstrations into working components from which integrated quantum systems will ultimately be built. That this can be done is by no means certain, hence the reluctance of the private sector to fund such research.

A critical component of this program is the formation of the Joint Quantum Institute with the University of Maryland and the National Security Agency. This Institute will work in all areas of the NIST quantum science program and will educate the next generation of quantum scientists and engineers through graduate student and postdoctoral fellowships.

In its Quantum Information Science Program, NIST will:

- Provide the Federal presence in quantum research that is necessary to attain long-term national goals, including national security,
- Begin bridging the gap between fundamental quantum science and new technologies by developing some of the quantum components needed for realization of a quantum computer, and
- Develop quantum measurement techniques applicable to the Nation's most fundamental measurement needs.

Enabling Nanotechnology: In order to enable advances in both basic science and industry in the field of nanotechnology NIST has developed a focused research program, the cornerstone of which is the Center for Nanoscale Science and Technology (CNST) that will provide the essential measurement methods, instrumentation, and standards to support all phases of nanotechnology development, from discovery to production. The program supports research in such areas as:

- Measurements and Standards in Support of Ultimate Complementary Metal Oxide Semiconductors (CMOS): The semiconductor industry, one of the largest value-added manufacturing industries in the U.S., has been highly successful in employing miniaturization to continuously increase performance of electronics at a constant cost. The industry will continue to push current methodology as far as possible to the endpoint of the development of CMOS technology, referred to as

Ultimate CMOS. Developing the ultimate in CMOS technology will require major advances in nanoscale measurement and standards. Equally important, is the search for technology that goes beyond Ultimate CMOS. NIST is partnering with industry and universities to provide the necessary measurements and standards to allow the development of Ultimate CMOS and post-CMOS platforms.

- Mechanical Properties of Nanostructures: A crucial requirement for developing advanced devices incorporating nanostructures is quantitative knowledge of the mechanical properties of the materials and structures within a device. This type of knowledge is necessary for optimizing device design, materials selection, manufacturing processes and reliability predictions. The mechanical properties of materials in nanostructures are often difficult to estimate and may be very different from their bulk counterparts. In addition, the mechanical properties of nanostructures themselves are often difficult to measure. The extremely small length scales both preclude the use of many measurement techniques applied at larger scales and introduce new surface-related phenomena. Consequently, challenges exist for nanostructure developers in understanding the relationship between structure and materials properties and in measuring mechanical properties of nanostructures. NIST will generate the measurement methods and standards for mechanical properties of nanostructures, focusing on those areas that will enable commercial development of new products.

- Three-Dimensional Imaging and Characterization of Nanostructures: Measurement techniques must dramatically improve as structures continue to shrink and as new types of structures are engineered for new functionality. These improved techniques are needed not only for the resolution of measurement, but also for the ability to discern three-dimensional complexity in the composition and arrangement of components within the structures. Characterization of the fine details of structure, chemical composition, and defect formation–in three dimensions with resolution appropriate to the nanostructure under study–presents an important and challenging measurement problem. Fundamentally new measurement capabilities beyond those achievable with current techniques will need to be devised and developed to meet these challenges for three-dimensional, non-destructive, imaging and characterization. NIST is developing:
  - New methods for detection and location in three-dimensions of defects, inclusions, and other irregularities in nanoscale structures;
  - Fabrication of three-dimensional, nanoscale chemical composition standard test structures with controlled elemental features;
  - New approaches for the characterization of properties of nanoparticles, nanocrystals, and quantum dots used in 3-D imaging applications;
  - A new ultrasound holography instrument for high-resolution three-dimensional imaging; and
  - A super-resolution optical method, validated at the 200 nm length scale, for 3-D imaging.

Environment, Health, and Safety (EHS) Measurements for Nanotechnology: Innovation derived from nanotechnology offers the potential for societal benefit, but like many new technologies raises questions about potential impacts to humans and the environment. It is essential to address the fate and impact of nanoparticles that enter our bodies and our environment in order to establish a science-based assessment of nanomaterials EHS risks.

However, studies of the EHS effects of nanoparticles are impeded by difficulties in characterizing the nanomaterials used. For example, when a toxic effect is observed, contamination of the nanomaterial in question and/or the presence of other nanomaterials can hinder evaluation of the underlying EHS risks associated with that specific nanomaterial. The absence of well-characterized materials and standard protocols make it impossible to compare and combine results from different laboratories. With no standard means to measure and determine the form and quantity of nanomaterials present, no one can definitively address the EHS risks of nanomaterials.

To fill this gap requires development of techniques and instrumentation to measure and characterize specific nanomaterials in environmental or biological systems. Specifically, NIST aims to develop methods for accurate detection and sizing of particles below ~100 nm with a focus on both microscopy and nonmicroscopy-based approaches that offer required speed and automation. Different measurement methods will be compared. Cutting-edge electron and ion-based microscopies as well as mass spectrometry techniques will be used for determining nanomaterial shape and structure. Standards for validation of these methods will be developed. Existing techniques for chemical and structural characterization with atomic resolution will be leveraged, and methods that provide information about the chemical structure of individual nanoparticles and the chemical structure of agglomerates of nanoparticles will be developed. Applicable approaches include a range of ion, electron and X-ray spectroscopies, microscopies and microanalysis techniques.

Cybersecurity: There is currently no generally accepted method for measuring the impact of attempts to improve cybersecurity. To address this gap NIST has launched a fundamental research program to develop the theoretical foundations of measurement science for complex information systems. Developing the measurement of information systems is multidisciplinary, involving the fields of discrete mathematics and theoretical computer science, and informed by metrics developed for the physical and biological sciences. The program will develop and analyze abstract mathematical models of information system structure and information flow, relying on the study of combinatorial structures (e.g., abstract networks and graphs), probability, information theory, dynamical systems, and control theory. Relevant models will be studied using the emerging theory of discrete random processes, queuing theory, and modern Monte Carlo-based computational approaches.

NIST work in this area will help create the needed infrastructure for cybersecurity metrics. These metrics in turn will allow companies, government agencies, and other organizations to improve the cost-effectiveness of their cyber security protection efforts by ensuring that the resources invested produce the expected cybersecurity improvements.

Measurements and Standards to Accelerate Innovation in the Biosciences: Current bioscience measurement capabilities are inadequate for dealing with complex biological systems and are still largely limited to studying only a few biological interactions at a time, often with methods that are only semi-quantitative. The limited use of standards and a lack of validated methodologies make much of the data and many of the models from bioscience research difficult to interpret and use in combination. Much of the data being generated is questionable in terms of reliability and repeatability, even standard measurements on a limited number of blood proteins often yield variable results between expert laboratories. Without a measurement infrastructure that can simultaneously measure significant numbers of biomolecules, and assure that the data collected are accurate, comparable, easily used, or correctly interpreted by others, innovation in the biosciences will continue to be stifled. Improvements in physical measurement and data handling tools and methodologies are necessary to maximize our Nation's investment in the life sciences.

NIST will build on its recent investments in bioimaging and biophysical measurements to create the measurement tools and standards that will enable the study of the complex interplay of thousands of genes, proteins and other biological molecules simultaneously. Initially, NIST will apply physical and chemical science expertise in microfluidics, microarrays, cellular imaging, single molecule measurements to develop quantitative measurement technologies and standards necessary for a traceable measurement infrastructure that can address the current barriers to the measurement and modeling of biological systems.

The efforts in physical measurement science will be accompanied by an informatics and computing infrastructure that includes computation, statistics, experimental design, and error analysis. The close combination of measurement technology and bioinformatics will assure that multiplexed measurements and data from different sources can be combined and analyzed appropriately to provide reliable models of complex systems. In future years, expansion of the NIST bioscience measurement program will enable the development of the measurement tools and infrastructure necessary for true systems level measurements. NIST will continue to collaborate closely with the NIH and Industry to ensure that the NIST biosciences measurement program addresses the highest priority measurement barriers of the life science community, as well as providing the next generation measurement technology for the biosciences.

Laboratory Exploratory Research: All nine NIST Laboratories actively encourage high-risk, basic research as part of the way they manage their research portfolios. This enables the Laboratories to support discretionary high-risk research opportunities as they arise. This flexibility is important as exciting advances in science and technology are often unforeseeable.

NIST FY 2009 Allocations for High-Risk Basic Research:

Funding for High-risk Basic Research		
Category	FY2008 Allocations	FY2009 Request
Source	**$ in Millions**	**$ in Millions**
Total STRS[2]	*439.6*	*549.6*
Innovations in Measurement Science	19.8	22.8
Cybersecurity	1.4	6.4
Enabling Nanotechnology	15	22
JILA	5.8	5.8
Quantum	6.6	13.6
Environment, Health, and Safety Measurements for Nanotechnology		12
Measurements and Standards to Accelerate Innovation in the Biosciences		10
Laboratories' Exploratory Research	5.5	5.5
Total High-risk R&D funding	**54.1**	**98.1**
% of STRS Committed to High-risk R&D	**12.3%**	**17.8%**

2 STRS or Scientific and Technical Research Services is the budget line item title that provides funds for the NIST Laboratories.

9.3 Appendix C: Report to Congress on NIST Efforts to Recruit and Retain Early Career Science and Engineering Researchers

EXECUTIVE SUMMARY

The America COMPETES Act (P.L. 110-69, Section 3011, August 9, 2007) directs the National Institute of Standards and Technology (NIST) to report on its efforts to attract and retain early career scientists and engineers. This report addresses the four key areas:

1. **Strategies** for attracting and retaining early career scientific and engineering researchers;
2. The **impact** of these strategies on the careers of early career scientists and on the research programs at NIST;
3. **Barriers** to recruiting and retaining early career researchers; and
4. **Funding** of recruitment and retention activities.

Building and maintaining world-class research programs are key elements in the recruitment and development of NIST staff. NIST leaders find that the best early career scientists and engineers are "motivated by the opportunity to do interesting and challenging work that makes a difference." It is essential that early career researchers be given the resources and scientific freedom to do leading edge research and become leaders in their fields. The best early career researchers expect and demand world-class facilities and superior scientific equipment. In addition, NIST offers an array of employment incentives and flexible human resource practices to compete with academia and industry for the best talent.

NIST takes the long view in nurturing and developing early career scientists and engineers by hiring students with an eye toward their ultimate success as scientific professionals. Talented early career scientists are encouraged by the recognition of their contributions and talent and NIST support for pursuing innovative, highly successful research projects.

To maintain our status as the preeminent scientific and engineering institution, NIST will need visionary leaders and increasingly flexible compensation and incentives programs to add to those inherent in NIST's Alternative Personnel Management System. NIST is continually challenged to find the right talent and skills to accomplish its mission. It is difficult to attract diverse Ph.D. scientists who are U.S. citizens. Vigorous outreach and employee development programs will help NIST maintain its high-caliber, high-performing workforce.

The America COMPETES Act will help NIST continue to attract and retain exceptional early career scientists and engineers. NIST has enjoyed success with programs such as the NIST/National Research Council (NRC) postdoctoral program, the Summer Undergraduate Research Fellowship (SURF) and Professional Research Experience Program (PREP) for undergraduates. Additionally, key partnerships with prestigious universities, industry and other government agencies—along with new investments in targeted outreach—can be expected to enhance NIST's standing as a world-class scientific institute.

INTRODUCTION

This report responds to Section 3011 of the America COMPETES Act of 2007 (P.L.110-69). Laboratory and program managers play a leading role in NIST's efforts to recruit and retain early career scientists and engineers and have maximum flexibility to use recruitment and retention incentives in meeting their organizations' staffing needs. In preparing this report, a questionnaire was used to compile information from the ten NIST laboratories on their successes and challenges in recruiting and retaining early career scientists and engineers.

This report presents an overview of the policies, procedures, financial and other incentives that allow NIST to continue as a world-class research organization, driving innovation, fostering industrial competitiveness, and improving the quality of life in a world economy that is increasingly dependent upon science and equitable standards. It also describes barriers to successful recruitment and retention, such as the scarcity of graduate programs in measurement science, the challenge of attracting a diverse scientific and engineering workforce, the high cost of housing and relocation, and the difficulty of hiring foreign nationals for highly specialized positions when no qualified U.S. citizen is available.

BACKGROUND

Historically, NIST has been very successful in recruiting and retaining early career scientists and engineers. That success is evident in scientific advances leading to the development of such innovative measurement tools as the atomic clock, scanning electron microscopy with polarization analysis, scanning tunneling spectroscopy, and robots to assist first-responders in disasters. Recommendations from NIST's three-year investigation of the World Trade Center disaster led to substantial changes in the U.S. building codes and standards. NIST employees have earned three Nobel Prizes, a MacArthur Fellowship, and a National Medal of Science—a reflection of the high-performing talent in this world-class research organization.

The questions from Congress are timely and useful because the competition for talented scientists and engineers is fierce. The NIST Alternative Personnel Management System (APMS) was created in 1987 upon a conceptual framework of total compensation comparability, market sensitivity, pay for performance, administrative simplicity, and management flexibility and accountability. It differs from the normal federal General Schedule (GS) system, with direct hiring authority for designated positions, selective use of higher entry salaries, and a simplified classification system. NIST also makes use of recruitment bonuses and retention allowances under both the federal government pay system and the APMS. As conditions have evolved, so has our APMS. The pay for performance system was modified last year to strengthen the link between performance and pay. As Congress has added new flexibilities for the federal workforce, such as student loan repayment, NIST added those to our "toolkit" for recruiting and retaining the best and brightest.

In addition to the traditional incentives, NIST makes a special effort to reward and recognize the contributions of early career scientists and engineers through the

Presidential Early Career Awards for Scientists and Engineers (PECASE) conferred by the White House, the Department of Commerce program of Gold, Silver, and Bronze Medal Awards, and fourteen NIST-specific annual awards. Prestigious fellowships and partnerships with the National Academy of Sciences, the National Research Council, the University of Colorado, the University of Maryland and other internationally renowned research institutions are powerful incentives to join the agency, and they also provide opportunities for NIST-trained professionals to go on to careers in academia and industry. As part of the America COMPETES Act, NIST now has been authorized to hire a greater number of these postdoctoral scientists and engineers, an important improvement in the Institute's efforts to attract top, early career talent. Partnerships with other federal agencies such as the National Institutes of Health also contribute to the "pipeline" of talent that will sustain our research and innovations in measurement science. Undergraduate programs are another key to NIST success in recruiting new talent, and this report provides several examples of how important those programs have been, especially as we face the challenges of underrepresentation of certain groups in scientific occupations. Most importantly, early career scientists are attracted to work with experienced NIST scientists who are recognized nationally and internationally for their expertise and achievements in science.

This report addresses the four items specified in Section 3011 of the America COMPETES Act:

1. A description of NIST policies and procedures, including financial incentives, awards, promotions, time set aside for independent research, access to equipment or facilities, and other forms of recognition, designed to attract and retain young scientists and engineers;
2. An evaluation of the impact of these incentives on the careers of young scientists and engineers at the NIST, and also on the quality of the research at the NIST's laboratories and in the NIST's programs;
3. A description of what barriers, if any, exist to efforts to recruit and retain young scientists and engineers, including limited availability of full time equivalent positions, legal and procedural requirements, and pay grading systems; and
4. The amount of funding devoted to efforts to recruit and retain young researchers and the source of such funds.

A description of NIST policies and procedures, including financial incentives, awards, promotions, time set aside for independent research, access to equipment or facilities, and other forms of recognition, designed to attract and retain young scientists and engineers.

Building and maintaining world-class research programs are key elements in the recruitment and development of NIST staff. As one NIST leader succinctly noted, "young scientists are attracted to senior scientists who have national and international visibility." NIST leaders find that the best early career scientists and engineers are "motivated by the opportunity to do interesting and challenging work that makes a difference." Therefore, it is vital that early career researchers be given the resources and scientific freedom to become leaders in their field. These research programs depend critically on world-class facilities and superior scientific equipment. Given the importance of a strong scientific base to improve the economic security and quality of life for all Americans, NIST uses an array of flexible and effective human resources practices to compete with academia and the private sector for the best early career scientists.

NIST research programs are world-renowned. Consequently, NIST attracts exceptional students and postdoctoral candidates. NIST boasts three Nobel Prize winners in Physics, one MacArthur Fellow, and one National Medal of Science recipient. The chance to work with such distinguished scientists is a major attraction for early career researchers. The majority of NIST laboratories reported the importance of placing early career scientists in leadership positions where they have the opportunity to develop scientific programs that move NIST forward to meet the measurement challenges of the 21st century. Early career scientists and engineers have many opportunities to contribute positively to innovative research such as NIST's cutting-edge "Innovations in Measurement Science" program. Early career scientists are given opportunities to attend important conferences and present significant papers. By attending conferences and presenting papers, early career researchers gain valuable exposure that increases their professional reputation with others in their technical field. NIST allows early career staff considerable latitude to pursue research efforts that they wish to do and that are consistent with the NIST mission. By providing opportunities to travel to conferences and to devote time to mission-related independent research, NIST has been successful in attracting and retaining talented early career scientists and engineers.

State-of-the-art laboratory equipment and instruments are vital to maintaining innovative research programs and recruiting the early career scientists and engineers who will lead NIST into the 21st century. For this reason, the President made the expansion of NIST's unique neutron imaging facility, the NIST Center for Neutron Research (NCNR), and the construction of high performance laboratory space at the NIST Boulder facility early centerpieces of the American Competitiveness Initiative. These facilities will complement the existing NIST facilities that early career scientists find so attractive, such as the Advanced Measurement Laboratory, the Center for Nanoscale Technology and the Advanced Chemical Sciences Laboratory. Each of NIST's scientific laboratories reported that access to specialized equipment and facilities is a powerful recruitment incentive.

One of NIST's strengths is its comprehensive outreach activities at all levels of education, including K-12 students and college and university students at the undergraduate, graduate, and postgraduate levels. NIST has a number of formal partnerships with universities, such as JILA, a partnership with the University of Colorado), the Joint Quantum Institute (JQI) and the Center for Advanced Research in Biotechnology (CARB) (both partnerships with the University of Maryland), and the Hollings Marine Laboratory (HML) (a partnership with the National Oceanic and Atmospheric Agency, South Carolina Department of Natural Resources, the College of Charleston, and the Medical University of South Carolina). NIST scientists and engineers participate in numerous and diversified outreach activities to attract early career scientists and engineers. Some outreach programs have concentrated on helping early career students make the transition from school to work while others have sought to encourage students to further their education, particularly in the areas of science, mathematics, engineering, and technology.

These programs are highly successful. The American Institute of Physics (AIP) recently assessed the NIST Summer Undergraduate Research Fellowship (SURF) program, which targets undergraduate students. AIP found that 98 percent of the participants indicated that SURF gave them a deeper understanding of what it is like to be a research scientist and 81 percent said that SURF helped them make a decision about their career. NIST laboratories frequently hire SURF and Professional Research Experience Program (PREP) students as guest researchers or permanent employees once they have completed their studies. A number of SURF alumni from underrepresented groups are presently employed by NIST. JILA has been an extremely successful because of the high caliber of research produced and as a training environment for future NIST leaders. This one relatively small program has produced over 70 NIST permanent staff and many SURF alumni are now in senior leadership positions at NIST. NIST expects that the newly formed Joint Quantum Institute with the University of Maryland, which contains aspects of JILA's structure, will produce similarly successful results.

It is critical that NIST have the ability to use a diverse set of human resources policies and procedures and programs to attract and retain the best and the brightest. Financial and other incentives have helped NIST retain its early career scientists and engineers. In addition to its extensive outreach efforts, NIST has the flexibility to offer competitive salaries compared to other federal agencies because of its Alternative Personnel Management System (APMS). NIST takes advantage of many programs, both monetary and nonmonetary, to attract and retain the talented early career scientists and engineers. In general, early career researchers respond most readily to incentives that include time for them to continue independent research relating to NIST's mission, stimulating colleagues, and state-of-the-art research facilities. Financial incentives are helpful but are not always the most influential incentives NIST has to offer. Some laboratories have even taken advantage of the student loan repayment program, a recently implemented policy, with other laboratories willing to use this incentive when appropriate.

Alternative Personnel Management System

NIST's Alternative Personnel Management System (APMS) established objectives in pay, position classification, recruitment, qualifications examination, retention, performance management, employee development, and employee relations. The APMS has aided in recruiting and retaining highly qualified scientists and engineers because of its flexibility in salaries and its streamlining of bureaucratic personnel processes.

Basic Features of the APMS include:

- **Recruiting:** NIST competes more effectively in the labor market through agency-based hiring, expanded direct hiring for hard-to-fill positions, greater management involvement in recruiting and hiring, flexible entry salaries, recruiting allowances; and more flexible paid advertising.
- **Retention:** NIST retains high performers more effectively through pay-for-performance, the higher pay potential of broad banding, supervisory differentials, and retention allowances.
- **Classification:** NIST has simplified, accelerated, and improved the classification process through broad banding, generic NIST-specific classification standards, automated position descriptions, and delegation of authority to line managers.
- **Administration:** NIST has streamlined the personnel administrative process through reduction of paperwork, automation of personnel processes, and delegation.

Student, Postdoctoral, and other Hiring Programs and Grants

NIST uses many programs to hire early career scientists and engineers. NIST hires students via student programs including the Student Temporary Experience Program (STEP), Student Career Experience Program (SCEP), and the Student Volunteer Program (SVP). NIST also runs the Summer Undergraduate Research Program (SURF) in partnership with the National Science Foundation. In Boulder, CO, NIST hires students through the Professional Research Experience Program (PREP).

NIST hires a number of postdoctoral candidates via the National Research Council's (NRC) program, as well from collaborations with other federal agencies such as the National Institutes of Health, and the intelligence community. The NIST/NRC Postdoctoral Associateship Program is highly competitive with 20-30 percent of the NIST/NRC postdoctoral associates being converted each year to term or permanent assignments at NIST.

NIST has collaborative partnerships with colleges, universities, and other federal agencies, including JILA, the Joint Quantum Institute (JQI), the Hollings Marine Laboratory (HML), and the Center for Advanced Research in Biotechnology (CARB).

NIST funds industrial and academic research in a variety of ways. For instance, NIST offers grants to encourage work in specific fields: precision measurement, fire research, and materials science. Many of these grants are awarded to universities, which help to expand their students' awareness of and involvement with NIST.

Financial and Nonfinancial Incentives

NIST has many financial incentives available to entice and reward outstanding early career scientists and engineers, including cash and time off awards, promotions, recruitment and retention bonuses, tuition reimbursement, and student loan repayment.

Awards – NIST is an employer of choice for many accomplished early career scientists and engineers not only for the financial incentives but also for other forms of recognition. For example, NIST offers nonmonetary recognition, such as the Department of Commerce Gold, Silver, and Bronze medal awards. NIST has had scientists win the Presidential Early Career Award for Scientists and Engineers (PECASE) each year of its existence. This prestigious award recognizes some of the nation's finest scientists and engineers who, while still early in their independent research careers, have demonstrated an exceptional potential for research and leadership at the frontiers of 21st-century science and technology. PECASE is the highest honor bestowed by the United States government on outstanding early career scientists and engineers. NIST scientists have regularly won the Arthur S. Flemming Award, which honors outstanding federal employees. Recognized by the President of the United States, agency heads, and the private sector, the winners are selected from all areas of the federal service. Recipients have at least three, but no more than 15 years of government service.

Work/Life programs – NIST's commitment to offering a family-friendly work environment enables early career scientists and engineers to balance work and family. Both NIST Gaithersburg, MD, and Boulder, CO, offer onsite childcare, fitness centers, and health units. Flexible work schedules are also popular.

Federal Benefits – As part of the federal government, NIST is able to offer outstanding insurance benefits including health insurance, life insurance, retirement, the Thrift Savings Program (a portable tax deferred retirement savings account), flexible spending accounts, long-term care insurance, health savings accounts or health reimbursement arrangements, and a separate dental and vision insurance program.

Developmental Details, Fellowships, and Collaborations – Four-fifths of NIST laboratories reported that developmental details help them retain current early career scientists and engineers. Such assignments allow scientists to expand their capabilities in key scientific areas. Employees have participated in details to the Office of Science and Technology Policy (OSTP) and other federal agencies. The OSTP detail allows early career scientists and engineers to explore the effects of science and technology on domestic and international affairs from a broad perspective. While on detail, NIST employees have the opportunity to develop science and technology policies and budgets, build partnerships among federal, state, and local governments, other countries, and the scientific community and evaluate the scale, quality, and effectiveness of the federal effort in science and technology. The COMSCI program is a 10-month competitive policy study and leadership program. Participants increase their knowledge and understanding of science and technology policymaking and management through exposure to "behind the scenes" experiences within the federal government, industry, and academia. Many of the participants are scientists and engineers in the earlier stages of their careers.

NIST encourages all of its scientists and engineers to collaborate with others in their work wherever and whenever it makes sense. Consequently, NIST has exchange programs with scientists from other countries who visit NIST to conduct research. These collaborations provide many opportunities for younger NIST staff to enrich their work and careers.

An evaluation of the impact of these incentives on the careers of young scientists and engineers at NIST, and also on the quality of the research at NIST's laboratories and in NIST's programs.

NIST laboratories have seen several different incentives make significant impacts on the careers of young scientists and on the quality of NIST research. NIST provides opportunities and resources that facilitate learning in a wide range of scientific areas, exposes early career scientists to world-class facilities and research, and allows them to do research without the burden of other responsibilities (e.g., fundraising, teaching) found in academia. Through its collaborations and partnerships with colleges and universities, NIST has provided an environment that has supported the work of early career researchers. The varied incentives and opportunities at NIST have created many "success stories" where early career NIST researchers have enhanced their own careers while making a measurable difference in the quality of NIST research programs.

All of NIST's scientific laboratories use special awards and recognition explicitly targeted at early career scientists. One of the most prestigious awards offered by the federal government is the Presidential Early Career Awards for Scientists and Engineers (PECASE). Many federal agencies participate in this award, and each year the President recognizes just four Department of Commerce scientists. This award helps early career scientists because it is highly prestigious and accompanied by up to five years of research funding. NIST PECASE recipients have gone on to serve as a payload specialist on the U.S. space shuttle, conducted research that would earn a MacArthur Fellowship, and led to discoveries that merited the Nobel Prize in Physics.

When NIST laboratories need to develop expertise in new directions, they frequently hire the best early career scientists to lead the next-generation programs. NIST gives these early career scientists and engineers the opportunity to build world-class programs and enhance their professional reputations. They are actively encouraged to pursue high-risk research, and this has paid off handsomely. These early career scientists and engineers have developed new scientific measurement tools such as scanning electron microscopy with polarization analysis, scanning tunneling microscopy with scanning tunneling spectroscopy. They have also initiated and developed significant new technical programs such as combinatorial methods, organic electronics, nanoscale magnetic materials, and biomaterials. Early career researchers have access to NIST's unique scientific facilities. At the NIST Center for Neutron Research (NCNR), one early career high-performing scientist conducted neutron scattering experiments using the dedicated computational facility to push the frontiers of science and contribute substantially to the quality of research performed at the NIST.

As noted above, NIST has many highly successful partnerships with academic institutions. These partnerships have a profound affect on NIST scientists, the students they supervise, and NIST as a whole. Through these partnerships, NIST early career scientists and engineers have developed teams of student researchers, pursued leading edge science, won prestigious awards, and trained the future generations of NIST leaders. Permanent staff scientists in the NIST Quantum Physics Division are also JILA Fellows and adjunct professors at the University of Colorado. These scientists sponsor graduate students as they do research in the NIST laboratories at JILA. Hundreds of the graduates from this program have gone on to successful careers; some have taken management positions at NIST, one became a Presidential Science Advisor and another became a Member of Congress.

NIST takes the long view in nurturing and developing early career scientists and engineers by hiring students with an eye toward their ultimate success as scientific professionals. Talented early career scientists are encouraged by recognition of their contributions and talent and NIST support for pursuing innovative, highly successful research programs. For example, one current program manager began his tenure at NIST as a summer employee in the Student Temporary Employment Program (STEP) as an undergraduate. The student returned each summer until he earned his Ph.D. and then became a NIST guest researcher while an assistant professor at a major research university. With NIST support, this scientist won several awards, including the PECASE award and the Arthur Flemming award. Now as a full-time NIST program manager, this scientist continues to serve as a mentor to students and to participate in professional development organizations. NIST’s support accelerated his career and allowed him to support the next generation of scientists while making significant contributions to the laboratory output.

A description of what barriers, if any, exist to efforts to recruit and retain young scientists and engineers, including limited availability of full time equivalent positions, legal and procedural requirements, and pay grading systems.

Efforts to recruit and retain early career scientists and engineers are decentralized at NIST, giving NIST managers flexibility to maximize the various programs to meet their needs. NIST managers were asked to identify and describe the barriers impeding recruitment and retention of early career scientists and engineers. Specifically, they cited as obstacles: a limited expertise base, limited funding for full time equivalent (FTE) positions, the high cost of living in the Gaithersburg, MD, and Boulder, CO, areas and the restrictions on the hiring of foreign nationals.

More than half of the laboratories indicated that the pool of applicants with expertise in the measurement sciences is limited. In certain disciplines, there is a need for immediate access to substantial expertise in new areas, which can lead to recruitment of senior researchers rather than new Ph.D.s. Because a limited number of university programs are dedicated to training scientists in measurement science, finding people with the right combination of skills can be difficult. NIST's partnerships with universities are an important attempt to overcome this challenge.

The availability of funding for additional full time equivalent (FTE) positions has traditionally been a challenge. However, given the support and expectations from the President and Congress for the American Competitiveness Initiative (ACI), NIST anticipates adding positions and will need the flexibility to adjust its FTE ceiling from the current level of 2,906. Current and future staffing needs are being carefully evaluated within the context of the ACI and national priorities for research and measurement science.

The difficulty in hiring noncitizens for NIST positions is also mentioned as a barrier. NIST, as a federal technical agency, follows the guidelines and procedures for implementation of Executive Order 11935 (September 2, 1976) for appointing non-citizens for competitive service positions covered by Title 5, United States Code (U.S.C.). We are able to accomplish a very small number of noncitizen hires as *Schedule A Excepted Service* indefinite appointments **when there are no available qualified U.S. citizens**. However, the procedure is lengthy and requires coordination with many offices and agencies to meet administrative, security, and other requirements. The procedure typically lasts months, and perhaps years, especially for a candidate who does not already have a permanent resident visa, and requires a final approval from the Department of Labor and the U.S. Citizenship and Immigration Services of the Department of Homeland Security in addition to approval from the Department of Commerce and the Office of Personnel Management (OPM). Streamlining the complicated process to allow more flexibility to hire noncitizens where no other suitable U.S. citizen can be identified would be of assistance in recruiting well-qualified scientists and engineers to NIST, as this category represents a significant and growing resource. As cited in the National Science Board *Science and Engineering Indicators 2006* (National Science Foundation, Vol. 1, NSB 06-01), degrees awarded by U.S. universities to noncitizen students accounted for most of the growth in science and engineering doctorates from 1983 through 2003, with 37 percent of doctoral degrees in the physical sciences and 51 percent of engineering doctorates being awarded to noncitizens. This trend was also cited by the National Academy of Science report *Rising Above the Gathering Storm*. The availability of some of this number of highly qualified scientists and engineers would assist NIST in building a high-quality workforce for the future when no U.S. citizen of comparable qualifications can be identified. It is recognized, however, that more hiring flexibility in this area may require broader government-wide procedural changes that extend well beyond NIST alone.

NIST also faces challenges in attracting a diverse scientific workforce. In FY 2007, NIST formed a workgroup to address this concern by developing a strategic approach to improving outreach, increasing diversity in hiring and retention, and reducing underrepresentation in NIST's scientific workforce. The workgroup includes key representatives from the Human Resources Management Division, Civil Rights and Diversity Office, and the Office of International and Academic Affairs. The workgroup developed a strategic recruitment plan aimed at coordinating outreach and recruitment efforts across laboratories to maximize impact and continue NIST's commitment to enhancing workplace diversity. Key elements of the plan include centralizing some aspects of recruitment to leverage economies of scale, strengthening partnerships between Human Resources, the NIST laboratories and selected schools, and improving measurement and accountability for results from management. Increased investment of time and money should yield better results, but this is a long-term proposition, and the first step is to improve diversity in the pipeline.

The amount of funding devoted to efforts to recruit and retain young researchers and the source of such funds.

NIST leaders have a record of investing in recruiting and retaining top early career scientists and engineers. These activities begin by creating a research environment that early career scientists find challenging and rewarding. These activities are integrated with the scientific research activities of senior NIST scientists. One of the most productive recruitment endeavors is the NIST/National Research Council (NRC) postdoctoral research program. Every year, NIST scientists promote post-doctoral research opportunities at hundreds of professional and academic conferences. Many NIST scientists have joint appointments with universities, exposing thousands of graduate and undergraduate students to NIST science. NIST integrates recruitment with core scientific activities—teaching and research—resulting in an extremely cost effective and productive program.

Most laboratories reported programs such as sponsorship of professional organizations, summer programs to serve students from high school to postgraduate levels, and the hiring of guest researchers from universities. NIST senior leaders also devote considerable time to recruitment and retention. The diversity of programs and participants in NIST's recruitment activities makes an aggregate estimate difficult to calculate. However, five NIST laboratories each reported estimates in excess of $200,000 per year, which includes staff salaries, expenses, travel, conferences, and recruitment events. All of these expenditures are funded out of NIST's Scientific and Technical Research Services (STRS) appropriations.

CONCLUSION

Early career scientists and engineers are attracted to NIST, and they tend to stay for long and productive careers. NIST has robust, vital research programs that give innovative and talented researchers opportunities to excel. NIST is a great place to work, with excellent benefits to complement the exciting work. Fast-moving sectors such as nanotechnology, quantum information science, homeland security, information technology, and advanced manufacturing need sophisticated technical support systems to flourish. NIST provides that support by continually improving the U.S. measurement system, developing new technologies, fostering standards, and providing both the business and technical evaluation tools needed to produce quality products and benefit government, industry, and academia.

Competition from academia and the private sector demands that NIST continues to employ the most effective recruitment and retention strategies to attract top scientific talent. To maintain our status as the pre-eminent scientific and engineering institution, NIST will need to employ progressive styles of management and leadership and make careful use of flexible pay and incentives inherent in the Alternative Personnel Management System. NIST is challenged with finding the right talent and skills to accomplish necessary scientific work. There are still underrepresented groups in the ranks of scientific doctoral graduates. It has been difficult to attract diverse Ph.D. scientists who are U.S. citizens. Increased investment in targeted strategic outreach and employee development programs will ensure that we maintain the quality of our people while improving diversity to match the diverse needs of the world economy and the changing labor pool.

Presidential and Congressional funding support for the American Competitiveness Initiative-related programs at NIST will be key factors in the Institute's ability to recruit and retain exceptional early career scientists and engineers. Successful programs such as the NIST/NRC postdoctoral program, the SURF and PREP programs for undergraduates, partnerships with prestigious universities, industry and other government agencies—along with new investments in targeted outreach—can be expected to enhance the exemplary standards set by the people who have made NIST an outstanding scientific institute.

9.4 Appendix D: Descriptions of Ongoing NIST Construction Projects

Building 1 Extension (B1E) – The FY 2007 CRF appropriation provided $10.1 million for NIST Boulder to initiate the design for the construction of an extension to Building 1 at a cost of $3.5 million and also to initiate site infrastructure work in support of the B1E project at a cost of $6.6 million. This project will provide unique, high-performance laboratory space with stringent control of temperature, vibration, humidity, and air cleanliness to meet the needs for the most demanding research and measurements conducted at NIST Boulder site. The FY 2008 CRF appropriation provides $23.6 million to begin construction of the B1E. An additional $43.6 million is requested in FY 2009, bringing the total estimated cost of constructing the B1E to $77.2 million.

JILA – In the FY 2009 President's budget, NIST proposes a CRF request of $13 million to expand the laboratories at JILA. JILA is a joint research institute of NIST at the University of Colorado of the highest class, in which the two institutions have forged important scientific advances together since the early 1960s. JILA currently houses the laboratories of three Nobel laureates, two MacArthur Genius prize winners, seven members of the National Academy of Sciences, and five members of the Academy of Arts and Sciences. The working relationship between JILA and NIST is mutually beneficial, and many of NIST's top researchers hold faculty appointments with the University. JILA is an international leader in Atomic, Molecular, and Optical (AMO) science—a field that the National Academy of Sciences says is "key to training our best scientists, engineers and technical professionals." NIST is the lead federal agency in AMO science, accounting for almost 40 percent of all federal funds for research in this area. Given current laboratory shortages at this world-class facility, further investment is integral in advancing novel research that has broad benefit to society, and in training the next generation of global research leaders.

The JILA expansion will increase JILA's capacity to train the next generation of AMO scientists by one third and the Nation's capacity by 10 percent. Current facility space is inadequate and constrains the number of researchers who can work in this field. The total cost of constructing the JILA expansion is estimated at $27.5 million. Colorado will contribute $5 million, and NIST proposes to contribute $13 million in FY 2009 and an additional $9.5 million needed in FY 2010. In addition, Colorado will supply the land and utilities infrastructure. The proposed funding continues an existing "institutional award" made to maintain the long-term partnership between NIST and JILA. Detailed analysis showed conclusively that expanding on existing space was the most cost-effective approach.

NIST Center Neutron Research (NCNR) – The FY 2007 CRF appropriation provided $12 million to initiate the design for the construction of a new guide hall facility for the NIST Center for Neutron Research (NCNR) and for construction costs of the cold neutron source and guide tube network that delivers intense neutron beams to the guide hall. The FY 2008 CRF appropriation provides $19 million to fund construction of a new guide hall and supporting facilities.

Safety, Capacity, Maintenance, and Major Repairs (SCMMR) – In the FY 2009 Congressional budget, NIST proposes a CRF request of $5.1 million for additional base funding in support of NIST's Safety, Capacity, Maintenance, and Major Repairs (SCMMR) program to facilitate the reduction of the deferred maintenance backlog. Over time, this increase will help to decrease the deferred maintenance backlog of safety, capacity, maintenance, and major repairs. The FY 2009 SCMMR base is $37.3 million.

9.5 Appendix E: NIST Initiative selection and evaluation criteria

9.5.1 Solicitation of FY 2010 Budget Initiatives and FY 2009 IMS Proposals:

Six-Page Proposal Instructions and Template

The Program Office is soliciting proposals for FY 2009 IMS proposals and out-year (2010) budget initiatives. Six-page proposals will be used to select candidates for both. Proposals for **FY 2010 budget initiatives will be due on December 19, 2007.** Proposals for **FY 2009 IMS projects will be due on February 28, 2008.**

The complete proposal should be no more than six pages and should demonstrate relevance to one of the four R&D focus areas outlined in the NIST R&D Priorities Memo (*initiatives that strengthen current core competencies; research that addresses the most strategic and rapidly developing technology areas; investments that expand the frontiers of measurement science; and research that addresses critical national needs*). Proposals should address the seven Heilmeier questions[3], all of which are embedded directly in the proposal template. All initiative proposals will be evaluated based upon the review criteria that were distributed to NIST staff along with the priorities memo on August 1.

The template asks you to list key selling points—the kinds of things that will be important when building a case for the merit of the proposal. Some general categories are listed below. Please indicate how any of these may apply. The more categories addressed, the better the chances of the topic moving forward.

Linkage to NIST and Administration R&D Priorities
Indicate the specific priority from the NIST R&D priorities memo or the OSTP and OMB budget guidance memo or other applicable Administration priorities.

Linkage to Interagency Working Groups
Indicate any connection to interagency working group positions on R&D needs or economic impacts that apply. This should include published reports or workshop results. It can also include workshop results or reports that are expected in the next three months.

Economic Impact Studies
List any economic impact studies that would support a case for doing this research and briefly explain how they apply (brief quote(s) would do). Indicate if there is a study underway that is expected to be completed in the next three months.

Strategic Relationships

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[3] As director of ARPA George Heilmeier had a set of questions he expected every proposal for a new research program to answer. He referred to them as the Heilmeier Catechism. They are: What is the Problem and why is it hard?; How is it solved today?; What is the new technical idea; why can we succeed now?; What is the impact if successful?; How will the program be organized?; How will intermediate results be generated?; How will you measure progress?; and, What will it cost?

Indicate any strategic relationships that would be relevant to this proposed initiative. An example would be an existing or planned collaboration with another federal agency that would support a joint effort.

9.5.2 Template for Six-Page FY09 Innovation Program, and FY2010 Initiative Proposals

Title:
Submitting OU:
Preferred Category (initiative or IMS):

Champion(s):
Please indicate who would be the initiative champion or innovation team leader(s).

What is the problem and why is it hard?
Please provide a brief summary of the topic or problem (one or two sentences)

How is it solved today, and by whom?
What is the current state of the art, and who is doing it?

What is the new idea? Why can we succeed now?
What critical idea or capability do we bring to the problem?

Technical plan:

- *Describe the challenge and the concepts to be examined.*
- *Describe the approach and how it is innovative.*
- *What are the goals, milestones, and deliverables?*
- ***How will you measure progress (e.g. stakeholder participation, number and quality of publications, CRADAs, etc.)?***

What is the impact if successful, and who would care?
What would NIST be able to accomplish if the proposal was funded?
Provide a summary of potential accomplishments and/or deliverables.
What would the benefit be to industry or society if NIST achieved its goals?
Indicate both who would benefit and some indication of the scale of the benefit.

Why should NIST do this?
Is NIST the appropriate place to do this work? Why should NIST do the work? (Note: These are two distinctly different questions.)

List Key Selling Points.

Possible other-OU Collaborations:

Identify other OUs that will collaborate if this is selected for further development.

How much and how long?
Give a preliminary estimate of the resources required for the program: number of FTEs, STRS or ITS funding, grant/contract funding, and IE funding. Only a brief statement of the required resources is needed. For example, "Year one: approximately 2 FTEs, $450,000 STRS, and $30,000 IE. Year two, approximately…"

9.5.3 NIST Initiative Evaluation Criteria

Corresponding Heilmeier Questions	**Evaluation Criteria**	**Scores**					**Weight**	**Total**
Why should NIST do this?	**Relevance:** *Is the project relevant to NIST's mission and aligned with Laboratory or NIST strategic directions? Is NIST the appropriate organization to do this work?*	**NO**				**YES**	**N/A**	**N/A**
		Low 1	2	3	4	High 5		
What is the problem and why is it hard? *How is it solved today and by whom?*	**Background:** o *Does the proposal show an understanding of the problem described?* o *Was it developed with broad stakeholder input? If so, who?* o *Does the initiative clearly link to the goals of the ACI?* o *Does the proposal articulate to what extent the initiative will impact the identified problem?*						1	
What is the new idea?	**Technical merit:** *Does the proposal demonstrate scientific and technical*						1.5	

	excellence? Does it present a new idea that could lead to success?							
	Project teams: o *Do the members of the project team have qualifications and accomplishments that indicate their ability to accomplish the project?* o *If the focus of the initiative is broader than the expertise resident within an individual OU does the project team contain membership from multiple OUs?*						1	
Why can we succeed now? *Technical Plan*	**Project Management:** o *Does the proposal clearly articulate the team structure and decision making process?* o *Does the proposal clearly articulate how interactions between project team members will occur throughout the project's lifetime?*						1	
	Technical plan: o *Does the proposal articulate how funds will be distributed across the project team over the life of the project?* o *Does the proposal describe how progress will be*						1	

	measured? o *Is there a clear technical plan with well-defined goals, milestones and deliverables?*							

What is the impact if successful, and who would care?	**Knowledge Transfer:**
	o *Does the proposal clearly articulate how the knowledge and results from the proposed initiative will be successfully disseminated to identified stakeholders?*
	  o *Partnerships*
	  o *Personnel exchanges*
	  o *Grants*
	  o *Products and services*
	  o *Strategic planning and roadmapping*
							1.5	

	Impact o *Is the potential payoff for NIST, our customers, and the nation substantial?* o *How will the initiative's impact be measured?* o *If the project were successful, who would care?*						3	
	Overall rating of the proposal							