Technology Innovation Program

Transforming America's Future Through Innovation

TIP

2008

ANNUAL REPORT

NIST National Institute of Standards and Technology • U.S. Department of Commerce

U.S. Department of Commerce
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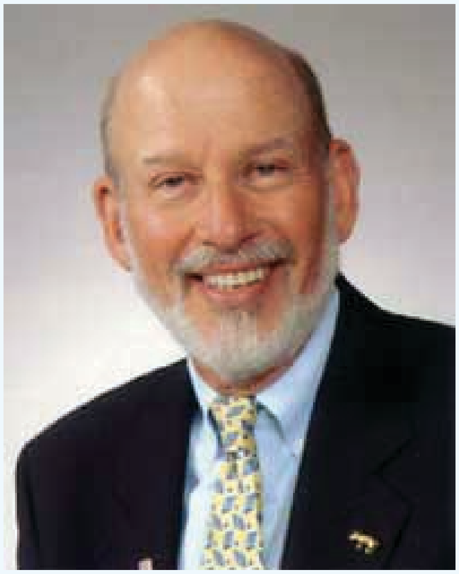
Director's Statement



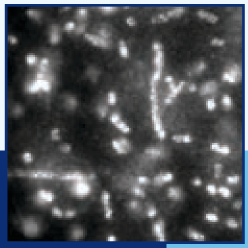
I am delighted to announce the first Technology Innovation Program (TIP) Annual Report. As pressure mounts regarding U.S. competitiveness in innovation, TIP strives to help the Nation's researchers find solutions to these growing concerns. The Program is attempting to fill the gaps within the federally funded research spectrum by providing resources to leverage technologies through high-risk, high-reward research that addresses emerging critical national needs. These are needs that challenge society's ability to respond to threats to the Nation's economy, environment, health, and safety.

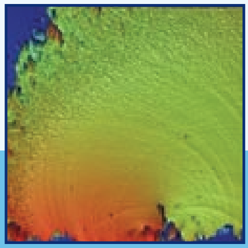
Whether the challenge is inspecting the Nation's infrastructure, reducing carbon emissions, or making personalized medicine a reality to name a few examples, TIP can leverage NIST technical expertise and its wide contacts with other agencies to forge public-private partnerships that are a key element in the development of technologies that can transform the way the Nation addresses societal challenges. These are very exciting times technologically, and TIP hopes to be at the forefront in the development of solutions that improve the way America competes in the future.

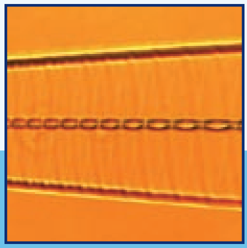
Despite the daunting challenge of getting up and running in a short period, much has been accomplished in TIP's inaugural year. During its first year, the Program completed its initial organization of staff and offices, published the Program rules, developed internal administrative processes, created the critical national need identification and selection processes, published a proposal preparation kit, conducted a competition, and made awards. The unprecedented speed with which TIP accomplished these tasks is due to the tireless efforts of the experienced and highly motivated TIP staff.

This first Annual Report details TIP's creation, examines the framework of the critical national need selection and competition models, looks at TIP's project management and impact assessment practices, and discusses the results of a gap analysis to determine the current areas of critical national need. It is my hope that this report and those in the years ahead will serve as focal points for discussion and technology policy guidance for government, academia, and industry.

Marc G. Stanley
Director
Technology Innovation Program
June, 2009







Defining the Program

What Is the Technology Innovation Program?

On August 9, 2007, the Technology Innovation Program (TIP) was created through the America COMPETES Act,[1] a comprehensive strategy to keep the United States the most innovative nation in the world by strengthening scientific education and research, improving technological enterprise, attracting the world's best and brightest workers, and providing 21st century job training. Part of the national strategy involved creating the TIP in the National Institute of Standards and Technology (NIST) in Gaithersburg, Md. TIP was established to help U.S. businesses, institutions of higher education, and other organizations—such as national laboratories and nonprofit research institutes—support, promote, and accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need. TIP aims to speed the development of high-risk, transformative research targeted to key societal challenges that are not being addressed elsewhere. Program funds will support research that has scientific and technical merit, as well as strong potential for advancing the state of the art and contributing to the U.S. science and technology base. Funding will be provided to industry (small and medium-sized businesses), universities, and consortia for research and development (R&D) on potentially revolutionary technologies to meet critical national needs. The research will carry high technical risks—and commensurate high rewards if it is successful. The primary mechanism for this support is cost-shared cooperative agreements awarded on the basis of merit competitions.

TIP was established to accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need.

Features

The major features of the Technology Innovation Program are established in the authorizing legislation. The following are some highlights:

- TIP has a novel purpose. TIP awards funding to high-risk, high-reward R&D projects that address critical national needs and societal challenges in any area that is important to the Nation but not being addressed by others. TIP has the agility to make targeted investments that are within NIST's areas of technical competence and are not possible by other mission-oriented agencies or programs.

- TIP supports rich teaming. Projects may be proposed by individual for-profit companies or by joint ventures that may include for-profit companies, institutions of higher education, national laboratories, or nonprofit research institutes, so long as the lead partner is either a small or medium-sized business or an institution of higher education.

- TIP is a public-private partnership. TIP makes cost-shared awards of up to 50 percent of total project costs. TIP may award a total of $3 million in direct costs over 3 years for a single-company

[1] America Creating Opportunities To Meaningfully Promote Excellence In Technology, Education, And Science Act (America COMPETES Act), P.L. 110-69

project or up to $9 million over 5 years for a joint venture.

- TIP supports small and medium-sized businesses. Large businesses may participate in a TIP-funded project, but they may not receive TIP funding.

- TIP complements—but does not duplicate—existing R&D efforts. TIP funds R&D that is not already being addressed, for which other funding (public or private) is not available, and for which government support is justified.

- TIP contributes to the U.S. knowledge base. Title to any intellectual property created through TIP funding will vest with the participating TIP award recipient company or with any joint venture member.

- TIP is part of the U.S. innovation system. An external TIP Advisory Board will provide advice on programs, plans, policies, and the general health of the Program.

- TIP will assess its progress and results. TIP will use state-of-the-art evaluation and assessment techniques to ensure optimal performance and results.

- TIP is part of NIST. NIST—the U.S. institution for advancing measurement science, standards, and technology—provides the Program with a rich innovation infrastructure consisting of groundbreaking research conducted by world-class physical scientists and engineers.

Organizing for Excellence

In September 2007, James M. Turner, deputy director of NIST, named Marc G. Stanley to serve as Acting Director of TIP. Stanley initiated a planning process and formed several teams to draft TIP regulations[2] and a proposal preparation kit,[3] recommend an organizational structure, design a Web site, review business processes, develop a strategy for external communications and outreach, and identify and develop potential critical national need areas that could justify TIP attention. TIP formally began operations on December 31, 2007. Stanley was named director, and 46 staff members from the former Advanced Technology Program (ATP) became TIP employees on January 1, 2008.

The first order of business was to develop and promulgate regulations, known as "the TIP Rule." The Rule provides an operational definition of the language in the TIP statute. It defines the competition process, establishes criteria for evaluation and selection of awards, and provides for dissemination of research results. It also establishes operational procedures, such as financial reporting and auditing, intellectual property rights, and other administrative matters. NIST published a draft Rule for public comment in the *Federal Register* on March 7, 2008, and accepted comments through April 21, 2008. After obtaining the necessary approvals from the Department of Commerce (DoC) and the Office of Management and Budget (OMB), NIST published the final Rule in the *Federal Register* on June 25, 2008.

In responding to critical national needs, TIP intends to realize the vast potential of the Program through the ability to fill gaps within the federally

[2] The TIP regulations are now 15 C.F.R. Part 296

[3] Published in June 2008 as the *TIP Proposal Preparation Kit*

Developing and Selecting Areas of Critical National Need

funded research spectrum. The key component of this Program and its eventual legacy will be the proficiency with which TIP is able to leverage high-risk technology to meet these societal challenges and solve problems of critical national need.

During its inaugural year, TIP established a pipeline of critical national need areas and selected one topic area in which to make its initial investments.

These are very exciting times technologically as new discoveries proliferate. TIP projects can leverage and combine those discoveries into useful tools that address problems of critical national need. As the U.S. faces major challenges internally and externally, TIP is prepared to be at the forefront in the development of solutions that improve the way America competes in the future.

During its inaugural year, TIP established a pipeline of critical national need areas and selected one topic area in which to make its initial investments. This section describes the process used to establish this idea pipeline, the criteria against which investment ideas were evaluated, and the wide range of input the Program received at various stages.

In developing a pipeline of critical national need topics, TIP used three guiding principles: (1) leverage, (2) consideration of a complete range of potential ideas, and (3) the application of consistent measures that allow comparison of different topic areas.

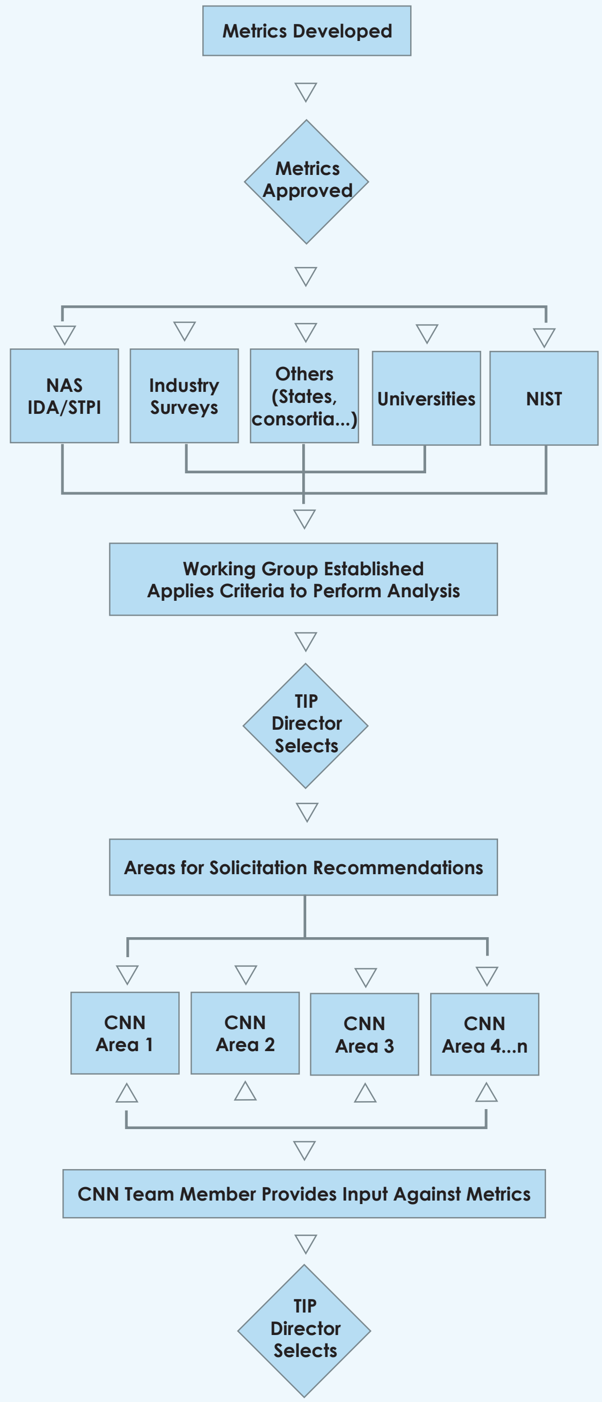


Figure 1

Note: CNN - Critical National Need; IDA - Institute for Defense Analyses; NAS- National Academy of Sciences; STPI – Science & Technology Policy Institute; TIP - Technology Innovation Program

The Process

Figure 1 illustrates the multistage process TIP developed to establish its pipeline of areas of interest for critical national needs investments for 2008. A distinguishing aspect of this process is that it incorporates expert opinion at key stages.

The first stage is the definition of the key metrics or criteria for evaluating potential critical national need areas. (This stage is discussed in detail in the section below on "Criteria and Evaluation Measures.")

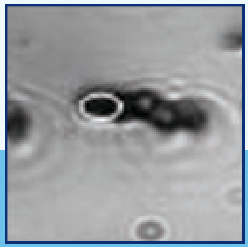
TIP examined a wide variety of input regarding critical national need areas. Potential topics came from government agencies and advisory bodies (such as the National Academies), the Science and Technology Policy Institute, industry organizations, leading researchers from academic institutions, NIST, and others. TIP also leveraged nationally recognized science and technology reports and know-how, and relied on sources such as the Office of Science and Technology Policy's annual budget priority memos defining key research directions for the Federal Government, industry roadmaps of technology needs, *An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation* (NIST Special Publication 1048), and other sources such as National Academies studies.

In the next stage, TIP established working groups to refine these potential topics for the TIP director's initial evaluation against the previously determined metrics. Some topics were ready for the next stage—preparing a detailed gap analysis and solicitation recommendation—while others needed more work. The TIP director used the same key metrics to select the solicitation topic for 2008 from among the more detailed recommendations.

Critical National Needs Evaluation Measures

- Mapping to Administration Guidance
  - To national objectives
  - To the NIST vision
  - To the TIP purpose
- Demand for Government Attention
  - Magnitude and nature of the problem
  - Societal challenge(s) unmet by others
  - Evidence of commitment
- Essentials for TIP
  - Expands scientific frontiers
  - Meets a timely need not met by others
  - Has potential for impacts and transformations
  - Fosters high-risk, high-reward research



Criteria and Evaluation Measures

In determining areas of critical national need, TIP developed a standard set of measures that allowed the director to systematically evaluate greatly differing areas and challenges and make an investment decision. To move forward, an area of interest had to map to Administration guidance, the demand for government attention, and essentials for TIP. For example, in addressing "mapping to Administration guidance," TIP sought direction from the Office of Science and Technology Policy's annual budget priority memos that list the Administration's key areas for research investment. The evaluation also considered how well the critical national need mapped to the NIST vision and to TIP's purpose of supporting, promoting, and accelerating innovation.

By conducting a gap analysis, TIP can identify specific avenues of research within a critical national need area that are not being addressed by others.

In examining the need for government attention, TIP addressed the magnitude and nature of the problem and the extent to which societal challenges were unmet by others. Finally, the alignment with TIP's purpose was addressed by examining the potential for the investment area to stimulate work on scientific frontiers, meet a timely need not met by others, deliver impacts and transformations, and foster high-risk, high-reward research.

A critical part of TIP's pipeline development work is its analysis of other Federal funding in a given area and the unique role TIP could play in addressing the critical national need and the societal challenge. By conducting a gap analysis, TIP can identify specific avenues of research within a critical national need area that are not being addressed by others.

Going Forward

TIP is continuing to identify areas of critical national need. TIP continues engaging thought leaders at such institutes as the National Academies, the Science and Technology Policy Institute, and NIST. On September 30, 2008, TIP issued a broad call for white papers defining areas of critical need and societal challenges. These white papers will give all interested parties the opportunity to describe problems and new directions for the program, which TIP staff can evaluate against the program's goals.

TIP will use these white papers together with workshops, industry roadmaps, and constituent surveys to develop new areas where a targeted investment in emerging technology could have a significant impact. TIP will systematically engage industry, universities, nonprofits, and other interested groups such as state and local governments to gather input and develop white papers that will contribute to future decisionmaking.

Critical National Need Choice and Potential Areas of Interest

Advanced Sensing Technologies for the Infrastructure: Roads, Highways, Bridges, and Water Systems was chosen as the inaugural area of investment for TIP. Because of budget constraints, only one area was selected from among numerous areas in which transformative research would have a large societal impact. Other fields considered included manufacturing, personalized medicine, water, energy, complex networks, and communication. These are all areas of critical national need that could be pursued in the future. This section provides background information on these potential areas of interest that may be useful for future competitions. (See the appendix for a more detailed discussion of these areas.)

Civil Infrastructure

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Civil infrastructure constitutes the basic fabric of the world in which Americans live and work. It is the combination of fundamental systems that support a community, region, or country. The American Society of Civil Engineers (ASCE) identifies these systems as aviation, bridges, dams, drinking water, energy, hazardous waste, navigable waterways, public parks and recreation, railroads, roads, schools, security, solid waste, transit, and wastewater. There is a *national* need for advanced sensing technologies, as every municipality and State faces infrastructure management challenges. The need is *critical* because although major parts of the infrastructure are reaching the end of their life spans, few cost-effective means exist to monitor infrastructure integrity and prioritize the renovation and replacement of infrastructure elements.

Damaged infrastructure directly affects the daily lives of a large number of Americans. The Nation has approximately a million miles of water mains, 600,000 bridges, and 4 million miles of public roadway. Public safety professionals and engineers responsible for this infrastructure strive to maintain these systems, prioritize repair schedules, and avoid premature replacement of infrastructure. More than 25 percent of the Nation's 599,766 bridges are structurally deficient or functionally obsolete.[4] Several societal challenges must be overcome, including inspection issues, monitoring issues, the development of new materials, "smart" structures, and green and sustainable construction. TIP has decided to focus on the challenges of inspection and monitoring to help secure the infrastructural integrity of the United States into the 21st century.

Civil infrastructure constitutes the basic fabric of the world in which Americans live and work.

[4] Research and Innovative Technology Administration. U.S. Department of Transportation. *Condition of U.S. Highway Bridges by State: 2007*. Available at http://www.bts.gov/current_topics/2008_04_24_bridge_data/html/bridges_by_state.html

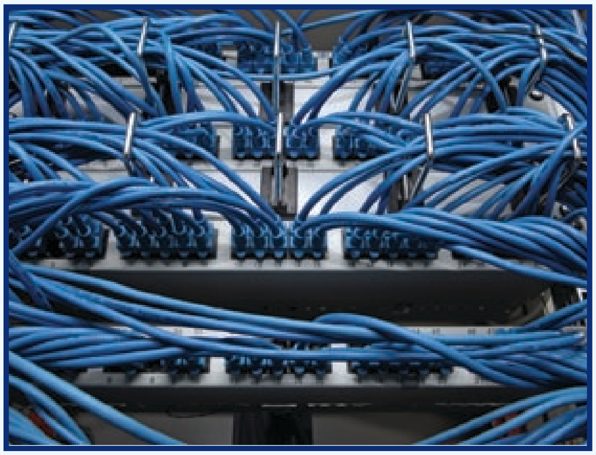
Communications

Communications are a vital part of U.S. society, accounting for more than $1 trillion in revenues per year (and growing rapidly). Annually in the United States, more than 68 billion telephone calls are made, and more than 180 billion e-mail and 350 billion text messages are sent. But today's complex communication networks, both wired and wireless, are vulnerable to unanticipated outages and security breakdowns, both natural (e.g., flood or earthquake) and man-made (e.g., terrorism). The challenges to achieving reliable and robust communications include the following:

- The prediction, prevention, and/or correction of potential communications problems before they become major disasters.
- Recovery from network interruptions.
- Integration of diverse types of communications components, subsystems, and network systems (e.g., fiber optics, copper cable, wireless) now in use, while still maintaining reliability and security in the network.

Addressing these challenges is vital to maintaining the Nation's communications infrastructure.

Complex Systems



Networks—biological, physical, and social—are pervasive in all areas of life. They are indispensable for the global economy and the defense of the United States against both conventional military threats and terrorism. For example, the linkage of information networks is creating a global information grid to which the majority of the world's population is likely to be connected within the next decade. The study of networks and their effects is a social, scientific, and technological imperative for the 21st century. But despite society's profound dependence on networks, fundamental knowledge about how complex networks behave is in a primitive state. We cannot reliably predict the behavior of networks under stress or the options that networks have to respond to changing environmental conditions. Specific technical knowledge gaps include the following:

- Modeling and analysis of complex networks. Tools, abstractions, and approximations are needed for manipulating large-scale networks, as well as techniques for modeling networks characterized by noisy and incomplete data.

- Design and synthesis of networks. Techniques are needed to design or modify a network to obtain desired properties.

- Experimental framework and measurement system for complex networks. Current data sets on large-scale networks tend to be sparse, and tools for investigating their structure and function are limited.

- Making networks robust to variations in the components (including localized failures) and secure against hostile intent.

Current levels of government and private sector funding are unlikely to encourage the systematic development of adequate fundamental knowledge about the behavior of large, complex networks.

Energy

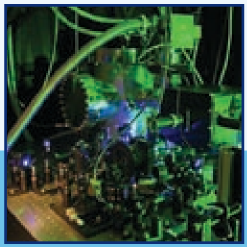
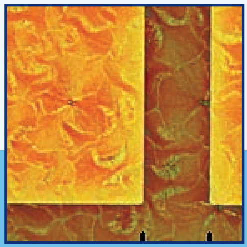
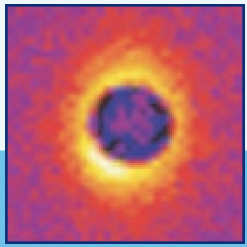
The U.S. economy is highly dependent on foreign sources of energy—a disruption in the supply of oil from foreign countries or a price increase significantly affects all sectors of the economy. Throughout the 21st century, energy access and costs will determine the quality of life and national security in the United States. The net import share of U.S. energy consumption was 30 percent in 2006; it is projected to remain about the same through 2030, leaving the country with significant national security issues and a negative

balance of payments. Approximately 47 percent of the $710 billion U.S. trade deficit in 2007 was the result of oil dependence. In addition, developing nations will contribute to a significant increase in worldwide carbon dioxide emissions; in particular, China will contribute 26.2 percent of the total by 2030.

Total U.S. energy consumption is projected to grow from 100 quadrillion Btu (QBtu) in 2004 to 131 QBtu in 2030. Other countries are competing for the same energy resources, and world energy consumption is projected to grow from 447 QBtu in 2004 to 702 QBtu in 2030. The development of renewable energy sources will provide a significant economic advantage. Energy-related carbon dioxide emissions in the United States are projected to grow from 5.89 billion metric tons in 2006 to 7.37 billion metric tons in 2030. Specific technical challenges include the following:

- Reducing U.S. dependence on foreign oil.

- Reducing carbon dioxide, nitrous oxide, and other greenhouse gases, which are major contributors to global warming.

- Identifying and developing renewable energy sources and technologies that are critical to economic stability and national security.

Manufacturing

Manufacturing is a vital part of our Nation's economy. The manufacturing sector supported 14 million jobs in 2007—about 10.1 percent of total employment. However, employment in manufacturing is at its lowest point since 1950; virtually every state lost manufacturing jobs between 2001 and 2004, with an average loss of 11.5 percent. Still, manufacturing industries are responsible for a significant share of U.S. economic production, generating $1.6 trillion in gross domestic product (GDP) in 2006 (12.2% of total GDP). U.S. manufacturing firms also lead the way in trade, exporting $923 billion in manufactured goods in 2006—64 percent of all U.S. goods and services exported. Gains in manufacturing are key to U.S. productivity growth. As the DoC report *Manufacturing in America* (January 2004) states, "A healthy manufacturing sector is key to better jobs, fostering innovation, rising productivity, and higher standards of living in the United States" (p. 7).

To remain competitive and ensure growth, manufacturers must address challenges in the following areas:

- Developing the ability to provide complex and individually customized products with improved quality, functionality, and performance. Rapidly changing market demands necessitate shorter innovation cycles, more flexible and rapidly reconfigurable manufacturing systems, integrated and streamlined communication and supply chains, reduced environmental impacts, and improved energy efficiency.

- Scaling up current experimental nanoscale processes from laboratory research to high-yield, high-productivity output. Delivering products from nanoscale manufacturing will require entirely new manufacturing processes and process controls based on sensing and measurement techniques that are well beyond the state of the practice and will require revolutionary new systems.

Personalized Medicine

The field of personalized medicine is attempting to unlock the vast implications of genetic variability within the human organism to significantly alter approaches to new drug development, diagnostics, and treatment regimens in the 21st century and beyond.

Annual per capita health care spending in the United States is high and rising ($5,635 in 2003 and $6,096 in 2004),[5] and currently approved drugs

[5] Goldman, Dana P. and Elizabeth A. McGlynn. *U.S. Health Care: Facts about Cost, Access and Quality*. Rand Corporation, 2005. Available at http://http://www.rand.org/pubs/corporate_pubs/2005/RAND_CP484.1.pdf

work for only a fraction of the population. Doctors are unable to select optimal drug treatments and dosages on the basis of a patient's unique genetics, physiology, and metabolic processes, which results in a certain amount of trial and error in treatment. Money is wasted on drugs that do not work, and patients suffer longer as they try to find the right treatment and endure the side effects of treatments that do not work. If these problems are not addressed, they could lead to spiraling health care costs and reduced quality of life. Employers and taxpayers will bear these costs, resulting in further losses of productivity and industrial competitiveness.

The genomics research funded by the National Institutes of Health (NIH) has produced an abundance of data; however, major challenges remain in understanding the complex biological systems in disease states and making personalized medicine a reality. For example, we need to learn what specific genetic information can lead to a better understanding of disease mechanisms and how to use that information to prevent and treat diseases. Understanding the connection between genetic variations and disease states could provide earlier and more accurate diagnoses and targeted treatments.

The following are some of the advanced tools and techniques that need to be developed:

- Rapid and cost-effective analysis of patient genomes (i.e., less than $100/genome in less than a day) to compare with disease states.
- Rapid biomarker identification and detection, and links to disease states.
- Real-time, nondestructive techniques to detect proteins in cells and tissues in the human body.
- Tools for multiple, integrated, real-time measurements of DNA, RNA, and proteins.
- Tools and techniques to collect and analyze massive amounts of information.
- Protection of personal data.
- Improved and low-cost systems for diagnostics, imaging, therapeutics, and targeted drug and vaccine delivery.

Water Availability

Readily available water is a key contributor to the growth of our Nation. With increasing population growth, climate variability, demands from industry, and a multitude of other factors, freshwater supplies are coming under stress. If not addressed, these stresses have the potential to cause the spread of disease and chemical poisons through freshwater distribution systems or to cause distribution system failures that will disrupt services or flood residences and businesses.

While the Federal budget includes funding for water-related issues such as drinking and wastewater systems, flood control, desalination, restoration, and wetlands, significant technical problems whose solutions would have an important positive influence on society are not being addressed. Estimates of the funding to repair, replace, or upgrade the Nation's drinking water systems range from an annual shortfall of $11 billion to a need for $151 billion over 20 years for 55,000 community drinking water systems.

Every day, 6 billion gallons of clean, treated drinking water disappear, mostly because of old, leaky pipes and water mains; this amount of water would serve the population of California. The Nation's reservoir dams are also problematic. The American Society of Engineers (ASE) has labeled 2,000 reservoir dams unsafe, and the Federal Emergency Management Agency (FEMA) has identified 10,000 dams as having a high hazard potential. Numerous recent publications have identified biological, chemical, and pharmaceutical agents in drinking water systems—clearly an area of critical national need. TIP has decided to focus on the challenges of inspecting and monitoring water distribution systems to help secure the infrastructural integrity of the United States into the 22nd century.

Green Chemistry

In the fall of 2008, as part of its efforts to continue development of new areas, TIP staff began development of a green chemistry critical national need topic area.

Although industry has made tremendous strides in transitioning to cleaner and safer chemical products, more than 7 billion pounds of toxic material were disposed of or released to the environment in the United States in 2006. Of particular concern, almost ½ billion pounds of persistent bioaccumulative toxic (PBT) chemicals were released. PBTs are highly toxic, long-lasting substances that are harmful to human and ecosystem health. They have been shown to be mutagenic, carcinogenic, and teratogenic.

Although large and critically important to the U.S. economy (employing almost 1 million people and producing $456 billion worth of goods and services), the chemical industry is highly energy and material intensive. The industry represents 2 percent of U.S. GDP while consuming 7 percent of total U.S. energy (and 25 percent of U.S. manufacturing energy use); further, more than 99 percent of chemical feedstocks (raw materials) are based on non-renewable fossil resources.

Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. It is an approach to chemistry that seeks inherently safer, cleaner, and more energy- and material-efficient products and processes.

The societal challenges associated with the advancement of green chemistry include the following needs:

- Fundamentally new, sustainable process chemistry, consistent with the principle that it is better to prevent waste than to clean it up after it is formed.
- Renewable chemical feedstocks, developed through technologies that derive chemicals from biomass in a sustainable manner.
- More energy- and cost-efficient chemical separation technologies, especially alternatives to distillation.
- Separation, sequestration, and utilization of CO_2 as a valuable input for entirely new materials, as opposed to considering it a harmful, undesired byproduct.

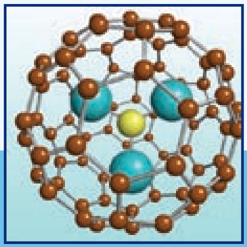
Building Strong NIST Collaborations

As part of NIST, TIP will establish scientific, technological, and strategic relations across the NIST organization and among stakeholders and customers that will enable the Program to achieve its mission and enhance NIST's world-class reputation. To do this, TIP is establishing scientific and programmatic collaborations that it believes will strengthen the Program and NIST's capabilities in areas of critical national need.

TIP is establishing scientific and programmatic collaborations that will strengthen the Program and NIST's capabilities in areas of critical national need.

TIP has undertaken a number of efforts:

- Launched the TIP Collaborations Team, which will work with NIST laboratories and programs to build relationships that will contribute to the success of both TIP and NIST.
- Conducted a number of briefings and joint activity discussions with a variety of NIST staff and professional groups, including Laboratory/Center Management, NIST Fellows, and others.
- Teamed with the Leadership and Employee Development Group in the Office of the NIST Chief Human Capital Officer to conduct a series of TIP focus group workshops. These workshops have included NIST leadership program graduates, group and project leaders, division chiefs, and former ATP detailees to solicit input on opportunities for cross-organizational teaming.
- Created a process for developing and assessing potential areas of critical national need that includes measures directly linked to NIST strategic objectives. The process includes NIST's most respected technical staff, the NIST Fellows, and involves other key NIST stakeholders, such as the U.S. Measurement System Office.
- Conducted joint outreach with the Manufacturing Extension Partnership (MEP). The TIP and MEP programs at NIST share many common characteristics. Both are extramural programs, working with U.S. industry to promote innovation in the domestic technology and manufacturing base. During TIP's inaugural year, a joint effort was launched to encourage discussion and provide information about TIP and MEP within the state science and technology community, to explore opportunities for collaborative efforts between the two programs, and to jointly support NIST studies, activities, and other efforts designed to provide important insights about how best to support U.S. innovation. Several activities are in the planning or early execution stages at this time.




The Program has begun to draw on NIST's scientific and technical expertise in a number of its functions. For example, in 2008, TIP relied on the technical expertise of NIST scientists and engineers to identify and select critical national need areas for TIP funding and for peer review of TIP proposals. Through its national need assessment efforts, TIP will facilitate communication among stakeholders and experts from across the Federal Government and NIST. The Program will expand collaboration in critical national need areas with experts from other Federal agencies and NIST to shape TIP's efforts, leverage other government activities, and help NIST uncover opportunities across groups. This is an important aspect of the integration of TIP across NIST and supports TIP's goal that other areas of the agency will benefit from TIP's work. Communication, collaboration, and participation in proposal review will expand the reach and scope of NIST's clients and enhance the agency's knowledge. At the same time, NIST's participation in the proposal evaluation and peer review process will help TIP realize its full potential.

TIP has taken a number of steps to attract the best and the brightest from NIST, DoC, other Federal agencies, and the private sector for extended appointments.

TIP has taken a number of steps to leverage existing programs and create new mechanisms that will attract the best and the brightest from NIST, DoC, other Federal agencies, and the private sector for extended appointments with TIP. These residencies will be an important mechanism for the ongoing development of TIP's programmatic capabilities. TIP has established links with the DoC Science and Technology Fellowship (ComSci) Program (http://comsci.nist.gov) and the National Academies Research Associateship Program to make TIP a destination for these leadership recipients. TIP is exploring the creation of similar links with the DoC Employee Leadership and Development Program, the American Association for the Advancement of Science (AAAS) Science and Technology Policy Fellowship Program, and programs at other respected institutions.

Structure of TIP

It is imperative that the TIP organizational structure effectively support the goals and mission of TIP. The Program is engaged in the far-reaching analytical activities of identifying and developing critical national need areas, the evaluation of cutting-edge scientific and technical proposals in new and diverse fields, and the intricacies and challenges of project and grant management as part of the oversight of financial assistance awards (grants or cooperative agreements). This requires an organizational structure that allows a highly qualified staff to apply the depth and breadth of their knowledge and skills to complex tasks, while retaining the rigor and discipline to meet deadlines and produce results.

TIP is a relatively flat organization, incorporating concepts of matrixed responsibilities and teamwork across four offices. Each office applies special expertise, knowledge, skills, and abilities to perform its core functions and to support and complement the work of the other TIP offices. All staff members are expected to apply their expertise and abilities to assignments and responsibilities that cross formal organizational boundaries. "Cross-office" work is routine. In addition, it was envisioned that scientists and engineers from NIST, other Federal agencies, states, institutions of higher education, and other organizations would work with TIP on short-term assignments to complement the skills and competencies of the core TIP staff.

The following are the four TIP offices established in March 2008:

The ***Selection Management Office*** is responsible for the full life cycle of planning and managing competitions, including proposal evaluation and selection activities, and the coordination of support and administrative functions. The staff in this office coordinate the selection of critical national need areas. They develop, coordinate, and execute plans to educate internal and external audiences about TIP.

The ***Project Management Office*** executes, funds, and manages multidisciplinary projects that span broad areas of science, engineering, and technology. The work by the staff in this office ensures that funded projects unfold in a manner consistent with the requirements of the TIP Rule, such as the award and evaluation criteria. Staff develop, demonstrate, and document best practices in project management. They maintain sector competency to ensure that this expertise is available to advance the TIP mission. This office also has primary responsibility for managing projects previously awarded under the ATP in accordance with the rules, procedures, and criteria of ATP.

The ***Impact Analysis Office*** monitors, quantifies, and analyzes TIP outcomes and impacts using state-of-the art assessment methods. Staff develop and report performance metrics and document the impact of TIP on addressing major societal challenges. This office is also responsible for producing the annual report to Congress.

The ***Office of the Director*** provides overall management and resource support to ensure the most efficient, high-quality outcomes across the organization. The *Administrative Support Group* provides document management and control services, often considered the "nerve center" for efficiently moving and protecting proposals through peer review during an active competition. The *Information Resources Group* provides comprehensive information technology (IT) systems, services, and applications, including maintaining the TIP Web site.

Creating External Links

The TIP statute calls for the creation of an advisory board with up to 10 members, at least 7 of whom must be from U.S. industry. The board is to reflect the diversity of technical disciplines and industrial sectors represented in TIP projects. Each member may serve up to 3 years.

The TIP Advisory Board will play a key role in guiding the organization. It will meet at least twice annually and will provide the director with the following:

1. Advice on TIP programs, plans, and policies.

2. Reviews of TIP efforts to accelerate R&D of challenging, high-risk, high-reward technologies in areas of critical national need.

3. Reports on the general health of the Program and its effectiveness in achieving its legislatively mandated mission.

4. Guidance on areas of investment appropriate for TIP.

In addition, the advisory board will produce an annual report on the status of TIP. The report will be provided to the Secretary of Commerce for transmittal to Congress no more than 30 days after the President submits his annual budget request to Congress.

A call for nominees for the TIP Advisory Board was published in the *Federal Register* on March 12, 2008. The Program will accept nominations on an ongoing basis.

TIP Outreach Strategy

The goal of the TIP outreach program is to provide general information about the Program to develop ongoing, robust relationships with key stakeholders and groups with an interest in research programs. Additionally, efforts are under way to develop ongoing dialogs with key stakeholder groups through which TIP officials can gather input about potential societal challenges and areas of critical national need that the Program should be considering for future competitions.

The goal of the TIP outreach program is to provide general information about the Program to develop ongoing, robust relationships with key stakeholders and groups with an interest in research programs.

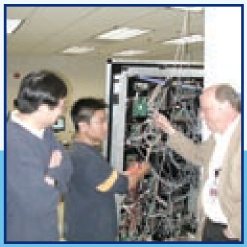
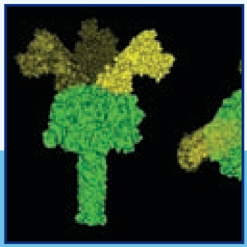
During TIP's first year, a staff team developed and executed an outreach strategy that focused on providing a basic understanding of the new Program to a broad, multifaceted audience. The team designed specific efforts and deliverables to reach as many people as efficiently as possible. They used a combination of Webcasts, personal visits, conference attendance, proposer conferences, and media coverage to disseminate a general overview of the Program and to publicize the details of the first TIP competition. Target audiences included state and local science and technology organizations, professional societies, other government agencies, academia, and industry.

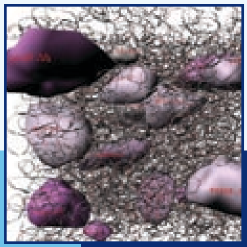
The TIP director conducted a series of outreach meetings and presentations to key groups identified as being critical to TIP, including the National Governors Association, State Science and Technology Institute (SSTI), Federal Demonstration Project, and a variety of state and regional organizations. TIP staff conducted additional outreach, including presentations and exhibits at conferences such as BIO 2008 (the annual global biotechnology event), as well as invited talks for groups such as the National Association of State Universities and Land Grant Colleges (NASULGC), the National Association of Manufacturers (NAM), the Interagency Network of Enterprise Assistance Providers (INEAP), and other state and regional events.

Outreach deliverables included a standard overview presentation, a brochure, a database of key contacts, displays for use in exhibits and conferences, and posters and other material.

NIST also supported TIP outreach. NIST Public and Business Affairs released several news items to its general mailing list and included TIP materials and literature in NIST booths and exhibits at technical conferences.

Plans for FY 2009 include a program of conference exhibitions and presentations targeted at audiences most likely to be interested in one or more potential critical national need topics that are under consideration and likely to have members who can participate in future TIP competitions. These include SSTI, the Defense Manufacturing Conference, NASULGC, the Association of University Technology Managers



(AUTM), in addition to technical conferences in technology areas under consideration. Events to promote critical national need idea development and gather input from interested parties will coincide with technical events—TIP will piggyback on activities where interested parties may already be attending. The plan in FY 2009 is to continue a regular series of Webcasts on a variety of topics related to the overall Program, competitions, and awards.

TIP will hold additional state and regional outreach forums, and implement a collaboration with MEP, using SSTI and NGA to facilitate a series of regional discussions on innovation in general and the two programs in particular. Some states have indicated an interest in more focused discussions designed to promote a better understanding of the Program and assist potential proposers.

TIP will create additional TIP collateral material and a full display booth for use in FY 2009.

Societal challenges do not just affect the Federal Government. We are also informing state governments about the opportunities TIP is creating for them. State government funds can be used to meet the company cost-share requirements; if state funding agencies are aware of and complementary to TIP's funding opportunities, more doors will open for small companies that do not have internal resources. To this end, TIP has been visiting states in all areas of the country and talking with technology transfer entities, economic development agencies, academic institutions, and other points of interest.

Competition Process

Introduction

The TIP competition process is focused on identifying the proposals that best meet the TIP award criteria and address the societal challenge defined in the solicitation. The goal of the process is to bring together all the expertise needed to identify these proposals.

The award criteria define the projects that TIP can fund; they are set out in the TIP Rule (15 CFR 296.22 (a) through (f)). The criteria support projects with specific characteristics that make them competitive. A project must demonstrate the appropriateness of taxpayer funding and the absence of other funding (criteria (a) and (b)). Because TIP aims to foster innovation, a project must be novel and have high scientific and technical merit (criteria (c) and (d)). And a project must show that it can affect a critical national need with transformative research (criteria (e) and (f)). The full TIP award criteria are as follows:

a. The proposal explains why TIP support is necessary, including evidence that the research cannot be conducted within a reasonable time period in the absence of financial assistance from TIP.

b. The proposal demonstrates that reasonable and thorough efforts have been made to secure funding from other funding sources and that no alternative funding sources are reasonably available to support the proposal.

c. The proposal explains the novelty of the research (technology) and demonstrates that other entities have not already developed, commercialized, marketed, distributed, or sold similar research results (technologies).

d. The proposal establishes that the research has strong potential for advancing the state of the art and contributing significantly to the U.S. science and technology knowledge base.

e. The proposal has scientific and technical merit, and may result in intellectual property vesting in a U.S. entity that can commercialize the technology in a timely manner.

f. The proposal establishes that the proposed transformational research (technology) has strong potential to address areas of critical national need by transforming the Nation's capacity to deal with major societal challenges that are not currently being addressed and generating substantial benefits to the Nation that extend significantly beyond the direct return to the proposer.

Description of the Process

Subpart B of the TIP Rule defines the multistage, multidisciplinary, peer-review competition process (see figure 2). Each stage involves tasks assigned to TIP staff as well as detailees from NIST and other Federal agencies, and everyone signs a nondisclosure agreement before handling any proposal. The first stage is a preliminary review to determine (1) whether the proposer is eligible to receive a TIP award and (2) whether the proposal is within the scope of the competition and addresses key components of the award criteria. The second stage consists of a peer review of the proposal against the evaluation criteria and a full evaluation panel deliberation of whether the proposal satisfies all award criteria. The evaluation panel ranks the proposals and presents funding recommendations to a selecting official, who reviews each recommendation and makes final recommendations to the TIP director. TIP staff prepare award packages for the selected proposals that include all required documentation and approvals. The packages are sent to the NIST grants officer for final review and approval.

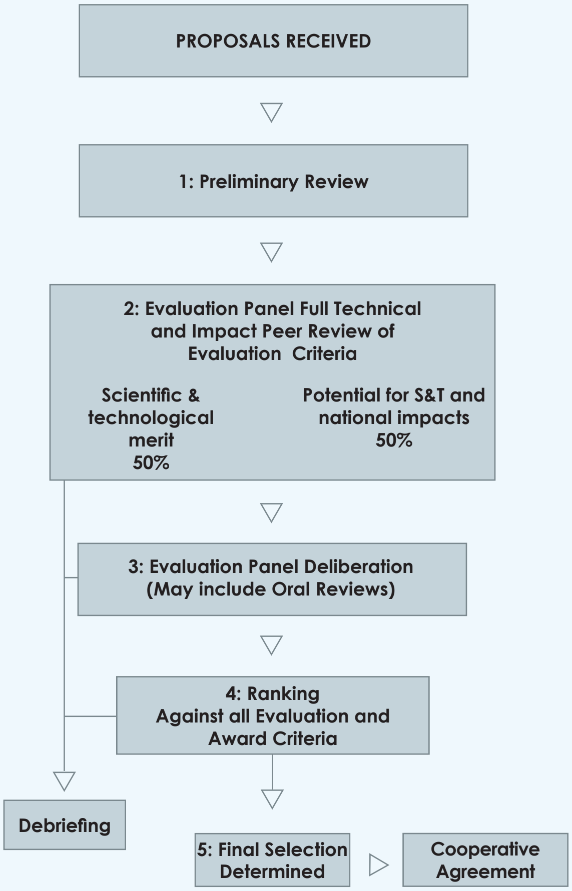


Figure 2: TIP Competition Process

Proposal Receipt and Inventorying Process

The *TIP Proposal Preparation Kit* describes the procedures for preparing and submitting a proposal. TIP accepts proposals in either electronic or paper format. Each proposal is assigned a unique identifying number.

Preliminary Review

Once inventoried, proposals are assigned to multidisciplinary preliminary review teams for the first stage of the competition process (defined in the TIP Rule at 296.20 (b)). The preliminary review determines whether the proposal meets the following requirements:

- Complies with Program eligibility requirements.
- Requests funds in conformity with the types of assistance available.
- Has a topic that is within the scope of the competition.
- Is complete.
- Addresses TIP award criteria (a) through (c).

Each proposal is assessed on each of these points. If the proposal meets the requirements, the preliminary review team recommends that it go forward; if not, the team recommends that the proposal be eliminated from further consideration.

Evaluation Panel

Once the preliminary review is completed, all proposals and the preliminary review team recommendations are passed to an evaluation panel. Each voting member of the panel has technical or industry experience and knowledge in the areas related to the critical national need. The panel makes the final determination as to whether a proposal passes preliminary review basing its decision on the preliminary review team recommendation, though it can override that recommendation. Accepted proposals are assigned to appropriate reviewers according to the technologies they involve.

Proposals that are not accepted are eliminated from the review process. These proposers are offered the opportunity to receive an oral debriefing at the end of the selection process.

The peer review addresses TIP's evaluation criteria—the scientific and technical merit of the proposal and the proposal's potential to achieve the necessary impact. The two criteria are weighted equally.

Peer Review

The peer review addresses TIP's evaluation criteria—the scientific and technical merit of the proposal and the proposal's potential to achieve the necessary impact. The two criteria are weighted equally.

The evaluation criteria are elaborated in the TIP Rule at 296.21:

a. The proposal adequately addresses the scientific and technical merit and how the research may result in intellectual property vesting in a U.S. entity, including evidence that

   1. The proposed research is novel.

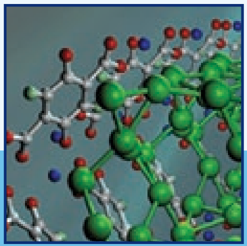
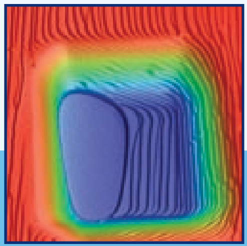
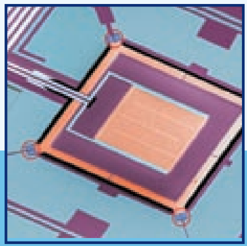
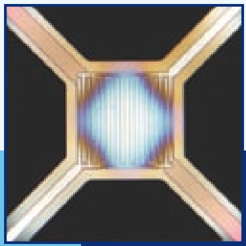
   2. The proposed research is high-risk, high-reward.

   3. The proposer demonstrates a high level of relevant scientific/technical expertise for key personnel, including contractors and informal collaborators, and has access to the necessary resources—for example, research facilities, equipment, materials, and data—to conduct the research as proposed.

   4. The research results have the potential to address the technical needs associated with a major societal challenge not currently being addressed.

   5. The proposed research plan is scientifically sound, with tasks, milestones, a time line, decision points, and alternative strategies.

b. The proposer adequately establishes that the proposed research has strong potential for advancing the state of the art and contributing significantly to the U.S. science and technology base; addressing areas of critical national need by transforming the Nation's capacity to deal with a major societal challenge that is not currently being addressed; and generating substantial benefits to the Nation that extend significantly beyond

the direct return to the proposer, including an explanation in the proposal of

1. The potential magnitude of transformational results on the Nation's capabilities in a specific area.

2. How and when the transformational results will be useful to the Nation.

3. The capacity and commitment of each participant to enable or advance the transformation to the proposed research results (technology).

Reviewers are chosen for their advanced technical expertise in the areas under consideration in the proposal and their knowledge of the sectors affected by the technology in the proposal. The reviewer pool consists of TIP, NIST, and employees from other Federal agencies who have scientific, technical, or industry knowledge in the specified area.

Deliberation and Ranking Process

Each proposal and the accompanying reviews are brought forward to the full evaluation panel for deliberation. All information is used in the deliberation, and the panel has the option of oral reviews with the proposers to gain additional information. Once all deliberations are completed, the panel ranks the proposals against the award criteria. The evaluation panel then makes a formal recommendation to the selecting official regarding which proposals to award. The selecting official makes the final decision from that recommendation based on the availability of funds, an appropriate distribution of funds among technologies, applications, and Program priorities.

Debriefing

Proposers whose proposals did not go forward at any stage of the review process will be offered the opportunity to receive a formal debriefing at the conclusion of the selection process.

Impact Analysis

Structure and Functions

Impact analysis will be provided through the Impact Analysis Office (IAO) at TIP. It is structured around four primary TIP functions: (1) monitoring awards and the surrounding economic conditions, (2) gathering and analyzing intelligence to assist in selecting areas of critical national need, (3) developing and disseminating intelligence to improve the Program, and (4) engaging the outside community to enhance TIP's ability to perform evaluation in areas of critical national need.

Monitoring

IAO's monitoring function consists of data collection, analysis, and communication. To monitor award recipients and the economic conditions in which they operate, data are collected from various sources, including current award recipients, the potential applicant pool, government sources, and commercial databases. Data will also be collected from completed TIP projects to determine the extent to which TIP met its mandate of supporting high-risk, high-reward R&D in areas of critical national need. TIP analyzes the data it collects to provide performance measures to key stakeholders, including the Administration, OMB, and Congress. IAO communicates these results through periodic reports, the annual report to Congress, and the TIP Web site.

Gathering and Analyzing Intelligence

Another key component of IAO's mission is to assist in selecting areas of critical national need. IAO develops surveys and analyzes the potential impact of Federal investment in critical national need areas. It determines where other organizations are making key investments and how TIP can complement those efforts, providing intelligence to decision makers on the appropriate role of Federal investment in key areas. IAO will also develop metrics that will allow policymakers to consistently evaluate potential investments in disparate areas of critical national need.

Improving the Program

Because TIP is an evolving organization, IAO will work with the Selection Management Office and the Project Management Office to analyze all primary TIP functions, including the proposal and selection processes, outreach, and customer satisfaction. Results of these analyses will be used to fine-tune the Program's direction and functions.

Engaging the Larger Community

IAO will work with other organizations to enhance TIP's ability to address areas of critical national need. These organizations include the National Opinion Research Center (NORC) of the University of Chicago, the National Bureau of Economic Research (NBER), the National Academy of Sciences (NAS), and the Science and Technology Policy Institute (STPI), as well as communities directly related to selected areas of critical national need. This year, these communities included the U.S. Department of Transportation, the Environmental Protection Agency, the Army Corps of Engineers, the Department of Agriculture, and the National Science Foundation.

Information and Data Collection Strategy

Data collection is a critical component of developing intelligence that TIP, the Administration, Congress, and the public at large can use. Data will be collected from stakeholders, applicants, award recipients, and the research community. Where possible, TIP will leverage existing data collection efforts to minimize the burden on respondents.

Primary data will be collected periodically with specific goals to meet core needs of the Program. These goals are to analyze the impact of the Program, monitor award recipients, monitor surrounding economic/industry conditions necessary for the development of critical national need definitions, and improve the Program. Because the primary data will be narrow and focused, IAO will augment its data collection efforts with special topics of interest when necessary. These special topics will be reflected in future annual reports, and will inform and respond to the needs of the TIP director, the TIP Advisory Board, the Administration, and Congress. For example, IAO might collect data on customer satisfaction, improving critical national need development, understanding technology transfer from universities, scientific workforce issues, or the role of states in TIP projects.

Initial analysis of TIP impacts will be geared toward scientific achievements that contribute to TIP's mission of overcoming societal challenges. IAO will initially measure inputs. Later, metrics for evaluating ongoing and completed projects may include the following:

- Characteristics of funded organizations.
- Measures of knowledge creation.
- Quantification of the state of the art before and after the project.
- Progress projects have made in addressing technical challenges.
- Value (monetary or otherwise) associated with such progress.
- Progress in transferring technology to the wider community.
- Productivity.

IAO will engage outside thought leaders, such as the National Academies, the Science and Technology Policy Institute, and the National Bureau of Economic Research, to assist in developing future metrics.

Best Practices for Managing High-Risk, High-Reward Projects

This section provides an overview of the framework for project management best practices, from the highest statutory and regulatory levels, through the policies of the Department of Commerce (DoC) and the National Institute of Standards and Technology (NIST), and finally to the Technology Innovation Program (TIP) approach (in conjunction with the NIST grants officer) to establishing, implementing, and communicating best practices to proposers, award recipients, and project managers.

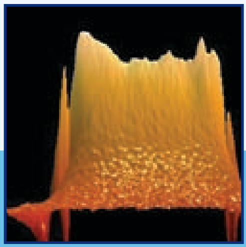
High-risk research projects are inevitably subject to change. Changes can take advantage of new opportunities or adjust the project due to unforeseen roadblocks. A flexible, facile interface between researcher and oversight organization, as well as cooperative engagement, is critical to making the responsibilities of being a recipient of taxpayer funds clear to awardees. At the same time, close monitoring is essential to responsibly managing the use of taxpayer funds, maintaining project fidelity to the original award, and maximizing the likelihood of project success under changing conditions.

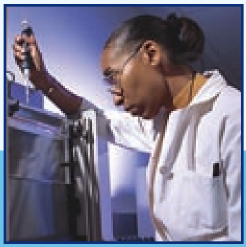
TIP's framework for best practices for project managers monitoring financial assistance awards under TIP is consistent with legislative, regulatory, and policy authorities. Project management is an important component of the Program and allows TIP to better meet its goals through hands on involvement in programmatic efforts during the funded period. Through direct contact, emails, and site visits, TIP project managers monitor the awardees and facilitate enhanced outcomes of the research to effectively use the taxpayer's dollars.

TIP's framework for best practices for project managers monitoring financial assistance awards under TIP is consistent with legislative, regulatory, and policy authorities.

For TIP—as part of NIST, an agency within the DoC—this includes the following:

- Statutory authority of 15 U.S.C. §278n;
- Implementing regulations set forth in 15 C.F.R. Part 296;
- Administrative requirements set forth in 15 C.F.R. Part 14;
- Applicable DoC authorities and policies, as presented in the *DoC Grants and Cooperative Agreement Interim Manual* (as amended);
- DoC Financial Assistance Standard Terms and Conditions (March 2008);
- TIP Proposal Preparation Kit (June 2008);
- TIP Guidelines and Documentation Requirements for Research Involving Human and Animal Subjects (June 2008);
- TIP Federal Funding Opportunity Notices (July 2008);





- TIP Federal Register Notice (July 2008);
- TIP General Terms and Conditions (December 2008); and
- TIP Special Award Conditions (December 2008).

Excerpts from the *Department of Commerce Grants and Cooperative Agreement Interim Manual* (see appendix B) provide the most concise summaries of the overall responsibilities and expertise required of those involved in monitoring TIP awards: the program officer, the grants officer, and the award recipient. Typically, the project manager reports to the program officer's designee; grants specialists report to the grants officer; and a designated principal investigator is the spokesperson for the award recipient. These roles comprise the team of experts that monitors project progress and compliance with award requirements.

Chapter 4, Section H of the *DoC Grants and Cooperative Agreement Interim Manual* details the responsibilities of the program officer, which are primarily focused on tracking the recipient's progress toward the goals established in the award.

Chapter 10, Sections E–F of the *DoC Grants and Cooperative Agreement Interim Manual* detail the recipient's responsibility to adhere to all the terms and conditions established by the DoC, including appropriate financial and accounting management and control over award funds. Monitoring may take the form of site visits, written and/or oral reports, meetings, or any other form of communication the grants officer deems appropriate to stay apprised of project progress.

Within this framework, project management tools and practices from proposal submission through final closeout of the project are established.

From the proposer's perspective, the Federal Funding Opportunity (FFO) notice is the introduction to the TIP approach to managing cooperative agreements. The FFO summarizes the guiding principles that TIP project managers will follow to monitor funded projects.

FFO, Section II, Award Information, describes the continuation process, which is based on satisfactory performance, availability of funds, and continued relevance. The funding instrument used in TIP awards is a cooperative agreement. Through the use of the cooperative agreement, TIP fosters public-private partnerships to support, promote, and accelerate innovation in the United States. Monitoring progress against established milestones and maintaining fidelity to the TIP award criteria are key elements for assessing performance and continued relevance. To prepare proposers for this project monitoring approach, the *TIP Proposal Preparation Kit* (June 2008) outlines the requirements of a competitive research plan (pp. 19–26) and explains the role of that plan in monitoring a funded project.

By its very nature, high-risk, high-reward research can run into unanticipated situations that require changes. Change requests from recipients are not unusual over the life of a project, and managing the evaluation and implementation of appropriate changes is a primary responsibility of TIP project managers. All proposed changes are evaluated in the context of maintaining the project's overall fidelity to Program award and evaluation criteria, and to meeting the administrative and legal requirements associated with any change. TIP uses the original research plan—which is scientifically sound and establishes clear tasks, milestones, metrics, time lines, decision points, and possible alternative strategies—as the framework for evaluating potential changes.

The recipient, grants specialist, and project manager will monitor the project through the life-cycle phases of the award, which include the following key activities:

1. Understanding the requirements of the award agreement, including applicable general terms and condition and special award conditions.
2. Participating in the site visit to kick off the award.
3. Meeting quarterly research and financial reporting and review requirements.
4. Meeting scheduled audit requirements.
5. Addressing project change issues (e.g., technical, financial, organizational, personnel) in a timely manner.
6. Tracking project impacts in nonproprietary formats.
7. Processing annual funding recommendations.
8. Participating in annual or other special site visits.
9. Participating in the closeout site visit.
10. Meeting the closeout technical, financial, audit, patent, property, and impact reporting requirements.

The Director of TIP's Project Management Office is responsible for establishing best practice performance expectations, as well as documentation and training modules to guide project managers in fulfilling their responsibilities, and for communicating effectively with recipients and grants specialists. Award recipients receive training materials in advance of kickoff, annual, and closeout site visits to help them prepare for the visits and to submit required followup information after the visits. These materials will be updated annually to incorporate lessons learned and any revisions to Program requirements.

Within this framework, project management tools and practices from proposal submission through final closeout of the project are established.

Continuous learning in project management best practices is intended to be a hallmark of the Technology Innovation Program.

This annual report has focused on the creation of the Program and its processes. Future reports are likely to provide specific details about critical national need development, discuss the progress of ongoing TIP projects, provide more information on the applicant base, and examine the characteristics of award recipients. As funded projects come to a close, TIP will provide information detailing the effects of the technologies that were developed. Future annual reports will also contain an analysis of the impact TIP funding has had on the state of technology and its applications in meeting critical national needs and solving societal challenges.

Future Annual Reports

Annually, TIP will identify the Nation's critical national needs, persisting societal challenges, the technology innovations that hold promise to offer solutions, and the gaps in Federal R&D assistance to develop these technologies. Future annual reports will examine the year-to-year changes in the U.S. innovation landscape and offer suggestions to help the United States maintain and increase its competitive advantage in innovation and, thus, the quality of life for its citizens.

Appendix A: Critical National Needs and Potential Areas of Interest

Civil Infrastructure

Civil infrastructure constitutes the basic fabric of the world in which Americans live and work. It is the combination of fundamental systems that support a community, region, or country. It plays a critical role in addressing the needs of civilization: improving quality of life, promoting economic growth, and protecting people from threats of natural and human origin. The civil infrastructure systems identified by the American Society of Civil Engineers (ASCE) include aviation, bridges, dams, drinking water, energy, hazardous waste, navigable waterways, public parks and recreation, rail, roads, schools, security, solid waste, transit, and wastewater. The need for advanced sensing technologies is *national* because every municipality and state faces infrastructure management challenges. The need is critical because portions of infrastructure are reaching the end of their life spans and few cost-effective means exist to monitor infrastructure integrity and prioritize the renovation and replacement of infrastructure elements.

Magnitude of the Problem

The ASCE 2005 *Report Card for America's Infrastructure* gave the Nation's public works an overall grade of D. It is estimated that $1.6 trillion is needed over a 5-year period to bring the infrastructure up to a B.

Damaged infrastructure directly affects the daily lives of many Americans. The amount of infrastructure to inspect is enormous. The Nation has approximately a million miles of water mains, 600,000 bridges, and 4 million miles of public roadway. Public safety professionals and engineers responsible for this infrastructure strive to maintain these systems, prioritizing repair schedules and to avoid premature replacement of infrastructure. ASCE estimates that Americans spend $54 billion each year in vehicle repairs caused by poor road conditions. More than 27 percent of the Nation's 599,893 bridges are rated structurally deficient or functionally obsolete. Total Federal spending of approximately $60 billion annually is well below the $155.5 billion needed to improve surface transportation infrastructure conditions nationally.

Societal Challenges

Several societal challenges must be overcome before we can address the deterioration of our Nation's civil infrastructure, including inspection issues, monitoring issues, the development of new materials, "smart" structures, and green and sustainable construction. The Technology Innovation Program (TIP) has decided to focus on the challenges of inspection and monitoring. This decision was based on an analysis of the size and complexity of the challenges and the expected benefits if they are met.

The need for improvements in cost-effective inspection and monitoring of critical infrastructure systems—especially bridges, roads, water delivery systems, and wastewater collection systems—can potentially be met with better and more cost-effective sensing technologies. Real-time data on the structural integrity of bridge components is not only useful to determine repair and renovation schedules but also essential for emergency evacuation in the event of impending catastrophic failure. There are currently no cost-effective, field-deployable sensing systems that are capable of providing continuous, quantitative data to meet these two needs. There has been progress in the development of embedded sensors for new construction; however, these systems are not deployable to existing components of the infrastructure.

Communications

Communications are a vital part of U.S. society, accounting for more than $1 trillion in revenues per year (and growing rapidly). Annually in the United States, more than 68 billion telephone calls are made, and more than 180 billion e-mail and 350 billion text messages are sent.

Magnitude of the Problem

Our complex communication networks, both wired and wireless, are vulnerable to unanticipated outages and security breakdowns, both natural (e.g., flood or earthquake) and man-made (e.g., terrorism). Outages and security breaches could have serious impact on U.S. commerce and trade, public health, transportation, emergency response, energy production and distribution, R&D, and the overall economic well-being of the country. Recent examples of communications disasters include the January 2008 fiber optic cable break in the Mediterranean Sea; the July 2001 fiber optic outage caused by a tunnel fire in Baltimore; communications breakdowns in the aftermath of Hurricane Katrina; and wireless interoperability problems during the World Trade Center rescues. Most such communications problems take days—or sometimes weeks—to correct, at enormous costs in lost commerce and even lives.

Societal Challenges

There are many societal challenges to achieving reliable and robust communications in the United States, including predicting, preventing, and/or correcting potential communications problems before they become disasters. If a communications breakdown does occur, the first challenge is to recover quickly. Other challenges involve integrating all the diverse communications components, subsystems, and network systems (e.g., fiber optics, copper cable, wireless) while maintaining reliability and security in the network. It is difficult to integrate the many diverse players that need to interact (e.g., phone companies, service/content providers, component manufacturers, IT companies), each of which has its own interests and needs.

Complex Systems

A *network* is a set of items, usually called nodes, with connections between them, called *edges*. They can be represented by mathematical *graphs*. At one time, the study of networks focused on the detailed analysis of relatively small graphs with perhaps a few hundred nodes; now it is common to study graphs with millions, even billions, of nodes whose connectivity properties can only be expressed statistically. The *complexity* of a network scales with the number of nodes and their interconnectivity. In the economic domain, networks include the air transportation system, highways, railroads, the global shipping network, power grids, water distribution networks, business-to-business (B2B) supply networks, global financial networks, telephone systems, and the Internet. In the biological domain, they include genetic expression networks, metabolic networks, our bodies, ant colonies, herds, food webs, river basins, and the global ecological web of Earth itself. Human society is profoundly dependent on complex, multiply interconnected networks, and this dependence will only increase in the future. However, our fundamental knowledge about them remains in a primitive state. Even though many networks have advanced technological implementations, their behavior under stress and their response modalities to changing environmental conditions are not well understood and cannot be reliably predicted.

Magnitude of the problem

One area of interest is the modeling and analysis of complex networks. We need to increase the level of mathematical rigor and the technical depth of our understanding of the structural and behavioral properties of complex networks. Current data sets on large-scale networks tend to be sparse, and tools for investigating their structure and function are limited. We need tools, abstractions, and approximations that will enable us to manipulate large-scale networks, as well as techniques for modeling networks characterized by noisy and incomplete data. We also need techniques to design and synthesize networks to obtain desired properties, and we need to develop an experimental framework and measurement system for complex networks. Finally, we need to design networks that are both robust to variations in the components (including localized failures) and secure against hostile intent.

Societal Challenges

Networks— biological, physical, and social— are pervasive in all areas of life. They are indispensable for the global economy and the defense of the United States against both conventional military threats and terrorism. For example, the linkage of information networks is creating a global information grid to which the majority of the world's population is likely to be connected within the next decade. The study of networks and their effects is a social, scientific, and technological imperative for the 21st century. Current levels of government and private sector funding are unlikely to encourage the systematic development of adequate fundamental knowledge about the behavior of large, complex networks.

Energy

The U.S. economy is dependent on foreign sources of energy—a disruption in the supply of oil from foreign countries or a price increase significantly affect all sectors of the economy. Throughout the 21st century, energy access and costs will determine the quality of life and national security in the United States. The net import share of U.S. energy consumption was 30 percent in 2006; it is projected to remain about the same through 2030, leaving the country with significant national security issues and a negative balance of payments. Approximately 47 percent of the $710 billion U.S. trade deficit in 2007 was the result of oil dependence. In addition, developing nations will contribute to a significant increase in worldwide carbon dioxide emissions; in particular, China will contribute 26.2 percent of the total by 2030.

Magnitude of the Problem

Total U.S. energy consumption is projected to grow from 100 quadrillion Btu (QBtu) in 2004 to 131 QBtu in 2030. Other countries are competing for the same energy resources, and world energy consumption is projected to grow from 447 QBtu in 2004 to 702 QBtu in 2030.

If the United States does not accelerate its development of renewable energy, development of such energy in other countries will give them an economic advantage. Fossil fuels are expected to continue to dominate energy consumption for the next 20 years. Currently, the United States derives 6 percent of its total energy from renewable sources, including hydropower. This level is expected to increase to only 7.5 percent by 2030. Although this would be an increase of over 3.1 QBtu in absolute levels, it still will leave the United States primarily a fossil energy consumer.

By comparison, Germany's target for renewable energy is 27 percent by 2020.

Carbon dioxide, nitrous oxide, and other greenhouse gases are significant contributors to global warming. Energy-related carbon dioxide emissions in the United States are projected to grow from 5.89 billion metric tons in 2006 to 7.37 billion metric tons in 2030.

Societal Challenges

- Eliminate or significantly reduce dependence on foreign sources of energy, which makes the U.S. economy vulnerable to instabilities in the energy-producing countries.
- Provide affordable and reliable energy supplies for the residential, commercial, transportation, and industrial sectors.
- Provide energy security for the people of the United States.
- Eliminate energy-related carbon dioxide emissions to significantly reduce environmental damage and improve the quality of life in the United States.

Manufacturing

Manufacturing is a vital part of our Nation's economy. The manufacturing sector supported 14 million jobs in 2007—about 10.1 percent of total employment. Manufacturing employs a higher share of workers without a college degree than the rest of the economy. On average, these workers earned 9 percent more than similar workers in the rest of the economy in 2006–07. Manufacturing industries are also responsible for a significant share of U.S. economic production, generating $1.6 trillion in GDP in 2006 (12.2% of total U.S. GDP). U.S. manufacturing firms also lead the way on trade, exporting $923 billion in manufactured goods—64 percent of all U.S. goods and services exported in 2006. Given the nexus between R&D and manufacturing, a vital manufacturing sector plays an important role in maintaining an innovative economy.

Magnitude of the Problem

With 14.3 million workers, manufacturing employment is at its lowest point since 1950; virtually every state lost manufacturing jobs between 2001 and 2004, with an average loss of 11.5 percent. The decline has been front-page news in many communities and nationally, and its effects are felt across the Nation. Long-term economic growth and competitiveness are at risk if these trends continue. Gains in manufacturing productivity are key to U.S. productivity growth. If manufacturing, R&D, and innovation continue to move offshore, an important part of our national economy will be lost; the wealth-enhancing aspects of these efforts forsaken; and a decline in U.S. economic growth all but assured.

Societal Challenges

A number of societal challenges are associated with the current state of manufacturing in the United States. A broad range of efforts is needed to transform manufacturing into a 21st-century engine of economic prosperity and innovation. The Department of Commerce report *Manufacturing in America* (January 2004) made recommendations for a comprehensive strategy to ensure that the Federal Government is doing all it can to create the conditions that will enhance U.S. economic growth and manufacturing competitiveness. Not all of these recommendations are within the purview of

TIP—some require regulatory changes or have policy implications that are outside the R&D area. However, they paint a complete picture of the needs of this sector and the challenges we face.

Specifically, to remain competitive and ensure growth, manufacturers must adapt to new challenges and market demands that require more complex and individually customized products with improved quality, functionality, and performance. Rapidly changing market demands necessitate shorter innovation cycles, more flexible and rapidly reconfigurable manufacturing systems, integrated and streamlined communication and supply chains, reduced environmental impacts, and improved energy efficiencies.

One societal challenge in the manufacturing arena that fits squarely within the mission of TIP is nanomanufacturing. Scaling up current highly experimental nanoscale processes from laboratory research to high-yield, high-productivity output will require entirely new manufacturing processes and process controls based on sensing and measurement that are well beyond the state of the practice, as well as revolutionary techniques and systems. Advances will need to draw on knowledge from the scientific community linked to the development of measurement and production tools and equipment. The ability to effectively and affordably develop and implement these processes will play a major role in the competitive posture of U.S. firms in the global economy. With $1.4 billion in revenue estimated for nanomaterials by 2008, a projected annual growth rate of more than 30 percent for the U.S. nanomaterials market through 2020, and a worldwide market for products using nanotechnology components estimated at $1 trillion by 2015, it is clear that investment in this area has tremendous potential impact.

Personalized Medicine

The need for personalized medicine is apparent in the following statements.

"Profound and persistent uncertainty, rooted in the limited knowledge of human biological systems and processes, makes drug R&D highly risky."[6]

"Much of the knowledge in the diverse disciplines that make up the biopharmaceutical sector is intuitive or tacit, rendering the task of harnessing collective learning especially daunting."[7]

The field of personalized medicine is attempting to unlock the vast implications of genetic variability within the human organism to significantly alter approaches to new drug development, diagnostics, and treatment regimens in the 21st century and beyond.

Magnitude of the Problem

Annual per capita health care spending in the United States is high and rising ($5,635 in 2003 and $6,096 in 2004),[8] and currently approved drugs work for only a fraction of the population. The Congressional Budget Office's June 2008 report, *Opportunities to Increase Efficiency in Health Care,* projects that net Medicare and Medicaid spending will increase from the current 4 percent of GDP to almost 20 percent in 2082.[9]

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[6] http://harvardbusinessonline.hpsp.harvard.edu/hbrsa/en/issue/0610/article/R0610HPrint.jhtml

[7] http://harvardbusinessonline.hpsp.harvard.edu/hbrsa/en/issue/0610/article/R0610HPrint.jhtml

[8] www.rand.org/pubs/corporate_pubs/2005/RAND_CP484.1.pdf

[9] www.cbo.gov/ftpdocs/93xx/doc9384/06-16-HealthSummit.pdf

Currently, doctors are unable to select optimal drug treatments and dosages on the basis of a patient's unique genetics, physiology, and metabolic processes, which results in a certain amount of trial and error in treatment. Money is spent on drugs that do not work, and patients suffer side effects. According to an article in *Business Week* (January 28, 2008), "Data suggest that for patients without heart disease, only 1 in 100 is likely to benefit from statins (e.g., Lipitor)."

It is estimated that the drugs that make it to phase III clinical trials fail 50 percent of the time.[10] The Food and Drug Administration (FDA) at the Department of Health and Human Services (DHHS) is not clear on how to provide regulatory oversight for designing trials based on personal data; it has therefore established a critical path initiative in personalized medicine. The Center for Medicare and Medicaid services lacks data for reimbursing only for patients who show treatment benefits. If these problems are not addressed, they could lead to spiraling health care costs and loss of productivity, quality of life, and U.S. industrial competitiveness.

In 2004, an independent nonprofit group, the Personalized Medicine Coalition (PMC), was formed to advance the understanding and adoption of personalized medicine concepts and products. On August 4, 2006, the Genomics and Personalized Medicine Act was introduced in Congress in an effort to overcome the scientific barriers, adverse market pressures, and regulatory obstacles to better medicine. In 2007, the FDA established a critical path initiative[11] to stimulate industry-wide efforts to identify the essential biomarkers and improve clinical trial designs that will accelerate product development. At its April 2008 meeting, the President's Council of Advisors on Science and Technology (PCAST) recommended that a Personalized Medicine Coordination Office (PMCO) be established within DHHS to provide oversight and coordinate activities related to personalized medicine across the DHHS agencies.[12]

Societal Challenges

Genetic variability creates differences between people in their susceptibility to diseases and their responses to drug treatment. Typically, this variability is within the 0.1 percent of the 3 billion bases of DNA that vary from person to person. The genomics research funded by NIH has produced an abundance of data. In 2004, NIH funded a $1,000/genome initiative to support low-cost genomic sequencing technologies[13]; in 2008, NIH announced an initiative in epigenomics to understand regulation of genes.[14] Major challenges remain in understanding complex biological systems in disease states and making personalized medicine a reality. For example, we need to learn what specific genetic information can lead to better understanding of disease mechanisms and how to use that information to prevent and treat diseases. Understanding the connection between genetic variations and disease states could provide earlier and more accurate diagnoses and targeted treatments.

These studies will require advanced measurement tools for high-throughput, automated, and cost-effective measurements to accurately identify, quantify, and characterize variations in

10 www.nist.gov/director/prog-ofc/report07-1.pdf

11 www.fda.gov/oc/oms/ofm/budget/2007/HTML/4CPPOM1.htm

12 www.ostp.gov/galleries/PCAST/April%202008%20KB%20PM%20Presentation.pdf

13 http://grants.nih.gov/grants/guide/rfa-files/RFA-HG-06-020.html

14 www.nih.gov/news/health/jan2008/od-22.htm

the components of the cell systems in real time without destruction of cells or tissues. We also need computational techniques for analyzing vast amounts of data and collecting meaningful information on disease states. The following are some of the advanced tools and techniques we need to develop:

- Rapid and cost-effective analysis of patient genomes (less than $100/genome in less than a day) to compare with disease states.
- Rapid biomarker identification and detection, and links to disease states.
- Real-time, nondestructive techniques to detect proteins in cells and tissues in the human body.
- Tools for multiple, integrated, real-time measurements of DNA, RNA, and proteins.
- Data collection and analysis of massive amounts of information.
- Protection of personal data.
- Improved, low-cost systems for diagnostics, imaging, therapeutics, and targeted drug and vaccine delivery.

The Technology Innovation Program at NIST will work with NIST scientists, PMCO, FDA, NIH, and others in the technical community to fill research gaps in these areas and define a complementary role for TIP in addressing the societal challenges in personalized medicine.

Water Availability

Readily available water is a key contributor to the growth of our Nation. With increasing population growth, climate variability, new demands from industry, and a multitude of other factors, freshwater supplies are coming under stress. If not addressed, these stresses have the potential to cause the spread of disease through freshwater distribution systems or to cause distribution system failures that will disrupt services or flood residences and businesses.

Although the Federal budget includes funding for water-related issues such as drinking and wastewater systems, flood control, desalination, restoration, and wetlands, significant technical problems are not being addressed. Solutions to these problems would have an important positive effect on our society.

Magnitude of the Problem

Recent news stories illustrate the magnitude of the water resource problems.

- Water availability is playing a greater role in decisions about industrial and economic growth. In February 2008, *The Economist* ran a story that discussed Florida's first ethanol production plant, being built in Tampa. The company had just submitted a request to use 400,000 gallons (1.5 million liters) a day of city water, which would make the facility one of the city's top 10 water consumers. And the company plans to double capacity shortly after production begins. Florida is suffering from a prolonged drought, and rivers and lakes are at record lows. So where will this extra water come from?

- While this would appear to be a regional problem, ethanol plant demands for freshwater are, in fact, a national issue. In 2007, President George W. Bush signed legislation requiring a fivefold increase in national biofuel production. Currently, the United States has 140 plants, with 60 plants under construction. A typical 50-million-gallon-per-year plant requires 500 gallons of water a minute to cool condensers. This level of demand has the potential to add significant stress to water systems in many areas of the Nation.

- Many people take for granted the ability to turn on a faucet and get safe, drinkable water. However, a number of studies suggest that our national water infrastructure is in dire need of attention. Surveys conducted by various organizations are raising concerns:

  - The ASCE assessed the drinking water infrastructure and found it to be in poor condition. Estimates of the money needed to repair/replace/upgrade the Nation's drinking water systems range from an annual shortfall of $11 billion per year to a need for $151 billion over 20 years for 55,000 community drinking water systems.
  - ASCE President William P. Henry noted in his March 9, 2005, remarks on the assessment that every day, 6 billion gallons of clean, treated drinking water disappear, mostly because of old, leaky pipes and water mains. This is an amount sufficient to serve the population of California.
  - The Nation's reservoir dams are also problematic. The American Society of Engineers (ASE) has labeled 2,000 reservoir dams unsafe, while the Federal Emergency Management Agency (FEMA) has identified 10,000 dams as having a high hazard potential.
  - A variety of recent news stories have identified biological, chemical, and pharmaceutical agents in drinking water systems. For example, on March 24, 2008, ABC News reported on a salmonella outbreak that spread through the water distribution system in Alamosa, Colo. More than 200 people became ill, and 9 were hospitalized. The governor declared a state of emergency, freeing up $300,000 in assistance. Ultimately, the system was flushed with chlorine, but the incident resulted in a significant disruption of services.

- The Associated Press recently reported on pharmaceutical agents such as antibiotics, anticonvulsants, mood stabilizers, and sex hormones in the drinking water supplies of at least 41 million Americans. The concentration levels are small—measured in parts per billion or parts per trillion, which is well below a medical dose. But while the drinking water is considered to be safe, scientists are concerned about the possible long-term human health consequences of these drugs. In this instance, additional information is needed before new regulations can be established.

Societal Challenges

The following are some of the societal challenges surrounding maintaining water quality:

- Approaches to data analysis, as well as estimates for data accuracy in water resource models (from local to global scales and for time scales on the order

- of weeks to decades or longer), are not integrated, which means that water managers cannot confidently administer water resources.

- Our inability to easily and reliably monitor and measure the level of damage in aging water infrastructure, so repairs can be prioritized, puts key freshwater resources at increasing risk.

- The lack of robust, real-time chemical and biological sensors for freshwater resource measurements and monitoring puts the Nation at risk of widespread health dangers from the freshwater infrastructure.

Green Chemistry

Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. It is an approach to chemistry that seeks inherently safer, cleaner, and more energy- and material-efficient products and processes.

Magnitude of the Problem

Although industry has made tremendous strides in transitioning to cleaner, safer chemical products (for example, the phaseout of CFCs), more than 7 billion pounds of toxic material were disposed of or released to the environment in the United States in 2006. Of particular concern, almost ½ billion pounds of persistent bioaccumulative toxic (PBT) chemicals were released. PBTs are highly toxic, long-lasting substances that are harmful to human and ecosystem health. They have been shown to be mutagenic, carcinogenic, and teratogenic.

In addition, the chemical industry is highly energy and material intensive. The chemical industry is large and critically important to the U.S. economy (113,000 establishments that employ almost 1 million people and produce $456 billion worth of goods and services), but it represents 2 percent of U.S. GDP, while consuming 7 percent of total U.S. energy (and 25 percent of U.S. manufacturing energy use). In addition, more than 99 percent of chemical feedstocks (raw materials) are based on nonrenewable fossil resources.

Societal Challenges

There are numerous societal challenges associated with the advancement of green chemistry to address these large problems. Areas we need to address include the following:

- Fundamentally new, sustainable process chemistry, consistent with the principle that it is better to prevent waste than to clean it up after it is formed.

- Renewable chemical feedstocks, developed through technologies that derive chemicals from biomass in a sustainable manner.

- More energy- and cost-efficient chemical separation technologies, especially alternatives to distillation.

- Separation, sequestration, and utilization of CO_2 as a valuable input for entirely new materials, as opposed to considering it a harmful, undesired byproduct.

Appendix B: Best Practices for Managing High-Risk, High-Reward Projects

Excerpts from the DoC *Grants and Cooperative Agreement Interim Manual:*

Chapter 4, Section H

"The Program Officer, or assigned operating unit component, is responsible for monitoring and oversight of the work being conducted under an award, such as tracking the recipient's progress and comparing the actual accomplishments with the goals and objectives established in the award. The Program Officer shall have sufficient experience, training, and expert knowledge in the specific program area and in program management in general, including knowledge of applicable laws, regulations, and Departmental policies as well as Program-specific goals, priorities and policies, to effectively manage the program area and to advise the Grants Officer on all programmatic aspects of the awards."

Chapter 10, Sections E–F

"Recipients of DOC financial assistance awards are responsible for achieving the scope of work and other activities delineated in the proposal as incorporated into their awards, and any DOC approved amendments thereto. Recipients are also responsible for ensuring that they comply with all of the terms and conditions of their awards and with the provisions made as part of the award including, but not limited to, exercising appropriate financial management, accounting, and control over award funds and other assets; and reporting to the Grants Officer and Program Officer as required under the terms and conditions of their award."

"The purpose of project monitoring is to ensure that the terms and conditions of awards are fulfilled. Project monitoring shall be the joint responsibility of the Grants Officer, Program Officer, award Recipient, and/or their designees. Monitoring may take the form of site visits, written and/or oral reports, meetings, or any other form of communication deemed appropriate by the Grants Officer for keeping apprised of project progress. See 15 CFR §§ 14.51-52 and 15 CFR §§ 24.40-41. Grants Offices and Program Officers may request audit assistance from the OIG in fulfilling their monitoring responsibilities. Allegations of fraud, waste, and abuse may also be referred to the OIG or made anonymously through the OIG Hotline at 1-800-424-5197."

Federal Funding Opportunity, Section II. Award Information

"Continuation funding is based on satisfactory performance, availability of funds, continued relevance to Program objectives, and is at the sole discretion of NIST.

"The funding instrument used in TIP awards is a cooperative agreement. Through the use of the cooperative agreement, TIP fosters public/private partnerships to accomplish a public purpose to support, promote, and accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need. TIP plays a substantial role beyond the levels required normally for Program stewardship of grants. This includes but is not limited to providing technical assistance and monitoring of the technical progress against established milestones, and maintaining fidelity against the TIP award and evaluation criteria; review and approval of key personnel, including the Principal Investigator (PI) and designated staff other than the PI; significant changes in project participants that impact the technical approach; and tracking impact statements for use in the TIP Annual Report."

Appendix C: 2009 Projects Funded

Technology Innovation Program 2008 R&D Awards Advanced Sensing Technologies for the Infrastructure

On January 6, 2009, NIST announced nine awards for new research projects to develop advanced sensing technologies that would enable timely and detailed monitoring and inspection of the structural health of bridges, roadways, and water systems that comprise a significant component of the Nation's public infrastructure.

The cost-shared awards initiate up to $88.2 million in new research over the next five years on structure monitoring and inspection technologies, $42.5 million of it potentially funded by TIP.

Development of SCANS^n for Advanced Health Management of Civil Infrastructures

Acellent Technologies, Inc. (Sunnyvale, Calif.)

- Project duration: 3 years
- Projected TIP contribution: $2,995,000
- Project cost-share contribution: $2,995,000

Acellent Technologies, Inc. (Sunnyvale, Calif.) plans an advanced intelligent sensor network using nondestructive evaluation techniques to monitor the structural health of entire bridges, buildings, and other major structures. A key feature of the planned Scalable Cognitive Autonomous Nondestructive Sensing network (SCANS^n) is the relative ease with which the network could be extended to cover larger and larger structures. If successful, SCANS^n will offer a relatively inexpensive, adaptable, and easily extensible network solution for monitoring the structural health of bridges, buildings, pipelines, and other major infrastructure components.

Fiber Sensing System for Civil Infrastructure Health Monitoring

Distributed Sensor Technologies, Inc. (Santa Clara, Calif., Joint Venture Lead)

- Project duration: 3 years
- Projected TIP contribution: $4,030,000
- Project cost-share contribution: $4,518,000

Distributed Sensor Technologies, Inc. (Santa Clara, Calif.) and joint venture partners Optiphase, Inc., (Van Nuys, Calif.); Redfern Integrated Optics, Inc., (Santa Clara, Calif.) and the University of Illinois at Chicago plan an innovative monitoring system for large structures such as bridges or pipelines that uses a single optical fiber sensing cable instead of potentially hundreds of discrete, local strain or fracture sensors. By replacing local discrete sensors with lengths of optical fiber, the system would mitigate initial deployment cost of the discrete sensors and a variety of bandwidth and transmission problems associated with collecting data from a large number of discrete sensors, while potentially offering more precise location of faults and problems. TIP support is required to pursue this project because the several technology development targets require a mix of both basic and applied research that is not addressed by other federal funding programs and that involves too much risk for private funding.

Infrastructure Defect Recognition, Visualization and Failure Prediction System Utilizing Ultrawideband Pulse Radar Profilometry

ELXSI Corporation (Orlando, Fla., Joint Venture Lead)

- Project duration: 3 years
- Projected TIP contribution: $3,119,000
- Project cost-share contribution: $3,629,000

The United States has more than 1 million miles of buried pipes carrying water to cities, towns, and homes. The consequences of pipeline failure range from disease-causing water pollution to sometimes fatal highway accidents due to sinkholes created by soil erosion around leaky pipes. Current practice is to inspect buried pipes with closed-circuit video cameras mounted on pipe-crawling robots, but the cameras can see only surface damage, not corrosion hidden by pipe liners or dangerous voids in the soil around the pipes. A joint research venture led by Elxsi Corporation (Orlando, Fla.) and including UltraScan, LLC. (Ruston, La.) and Louisiana Tech University (Ruston, La.) plans to develop an entirely novel approach to the problem using a technology called ultrawideband (UWB) pulsed radar that only became available in the past few years. In addition to identifying places where soil has been washed away near the pipe, the proposed system will be able to measure the current wall thickness of the pipe, the dimensions and depth of circumferential cracks and defects in the pipe wall, the integrity of internal reinforcement rods, and the amount of deformation of the pipe. TIP support is needed for this project because it involves several challenging technology development components, particularly the signal-processing software.

Microwave Thermoelectric Imager for Corrosion Detection and Monitoring in Reinforced Concrete

Newport Sensors, Inc. (Irvine, Calif.)

- Project duration: 3 years
- Projected TIP contribution: $1,249,000
- Project cost-share contribution: $1,249,000

Deterioration and failure of civil engineering structures due to rebar corrosion in reinforced concrete costs the Nation tens of billions of dollars annually. Newport Sensors, Inc., (Irvine, Calif.) plans a novel microwave "camera" for *in situ*, real-time nondestructive detection of rebar corrosion at an early stage. The proposed system exploits the fact that even a small degree of corrosion around a steel rebar or tendon acts as a thermal insulator, so corroded steel cools more slowly than uncorroded steel. If successful, the project innovations will enable direct visualization of rebar corrosion in its early stages, something not possible with any existing nondestructive evaluation technology, and will enable lower-cost repairs.

VOTERS: Versatile Onboard Traffic Embedded Roaming Sensors

Northeastern University (Boston, Mass., Joint Venture Lead)

- Project duration: 5 years
- Projected TIP contribution: $9,000,000
- Project cost-share contribution: $9,802,000

A research team headed by Northeastern University (Boston, Mass.) and including the University of Massachusetts at Lowell, the University of Vermont and State Agricultural College (Burlington, Vt.) and Witten Technologies, Inc., (Somerville, Mass.) plans to eliminate the need for setting up hazardous and congestion-prone highway work zones to conduct roadway inspections with an automated "drive-by" inspection system that uses ordinary vehicles in the course of their regular driving. The VOTERS (Versatile Onboard Traffic Embedded Roaming Sensors) project proposes to gather accurate, up-to-date condition information on roadways and bridges using compact instrument packages that would be installed in cars and trucks. The packages will include several novel and sophisticated sensor developments. An onboard computer will control the instruments, check its location using GPS, and report data back to base stations using the cellular phone system—all without involving the vehicle's driver, who just needs to follow his or her regular driving routine. If installed in a diverse fleet of vehicles, VOTERS will provide a constant stream of information on road and bridge deck conditions gathered under real, daily driving conditions at operational speeds that will not congest traffic. The information will allow planners to schedule needed repairs at the right place and at the right time.

Self-Powered Wireless Sensor Network for Structural Bridge Health Prognosis

Physical Acoustics Corporation (Princeton Junction, N.J., Joint Venture Lead)

- Project duration: 5 years
- Projected TIP contribution: $6,930,000
- Project cost-share contribution: $6,969,000

A joint venture led by Physical Acoustics Corporation (PAC, Princeton Junction, N.J.) and including research partners Virginia Tech (Blacksburg, Va.), the University of South Carolina (Columbia, Sc.) and the University of Miami (Coral Gables, Fla.), plans to develop a suite of new technologies that will enable an easily deployed, self-powered network of wireless sensors, together with analysis tools, to provide continuous monitoring of the structural integrity of bridges. The system will include an innovative system for "harvesting" its own power from ambient motions and vibrations in the bridge using piezoelectric materials. Built-in self-check capabilities will eliminate the need for routine sensor maintenance. The power harvesting feature will eliminate the need for either a hard-wired power source for the hundreds of sensor nodes required or a reliance on batteries that would have to be regularly replaced. This aspect greatly reduces both installation and maintenance costs for the monitoring system. TIP support is needed to offset the several high-risk elements of the proposal.

Next Generation SCADA for Prevention and Mitigation of Water System Infrastructure Disaster

University of California at Irvine (Irvine, Calif., Joint Venture Lead)

- Project duration: 3 years
- Projected TIP contribution: $2,800,000
- Project cost-share contribution: $2,885,000

A research team led by the University of California at Irvine and including Earth Mechanics, Inc. (Fountain Valley, Calif.), the Irvine Ranch Water District (Irvine, Calif.), the Orange County Sanitation District (Fountain Valley, Calif.), and the Santa Ana Watershed Project Authority (Riverside, Calif.) plans to develop a novel monitoring and inspection system for large water pipe networks. This advanced SCADA (Supervisory Control and Data Acquisition) system will incorporate several novel features to monitor both networks of pressurized pipes, commonly used for water supply, and unpressurized gravity pipes generally used for wastewater. SCADA will use noninvasive external sensors to monitor vibrations at the pipe surface, listening for the sharp transient jolts caused by a sudden local change in pressure or other hydraulic conditions, and highly innovative data fusion techniques to locate the source of the vibration. A particular feature of the proposed system is the ability not only to detect a fracture or failure in a pipeline but also to evaluate in real time the remaining useful life at the original design capacity in the damaged system, enabling more effective and strategic planning of repair operations and maintenance. The project success will aid in extending the useful life and reliability of the water systems infrastructure.

Cyber-Enabled Wireless Monitoring Systems for the Protection of Deteriorating National Infrastructure Systems

University of Michigan (Ann Arbor, Mich., Joint Venture Lead)

- Project duration: 5 years
- Projected TIP contribution: $8,998,000
- Project cost-share contribution: $10,164,000

A joint venture led by the University of Michigan (Ann Arbor, Mich.) with research partners Weidlinger Associates (New York, N.Y.), SC Solutions (Santa Clara, Calif.), LFL Associates (Ann Arbor, Mich.), Monarch Antenna (Ann Arbor, Mich.), and Prospect Solutions (Albany, N.Y.), plans to develop a comprehensive system for monitoring the structural integrity of systems of bridges by combining innovations at length scales ranging from individual structural components of a single bridge up to the regional management of a collection of bridges. Together the team will develop a suite of technologies to identify fatigue and corrosion in bridges, two closely related degradation mechanisms that if left unchecked lead to brittle structural failures. At the most basic level, these focus on self-sensing "smart materials" that can be incorporated into the structure of the bridge and can detect localized failures, like cracks. Power "harvesting" technologies based on electromagnetic and micro-electromechanical (MEMS) devices that derive power from vibrations in the bridge structure will power the system. Other innovative elements include an Internet-based system that links data streams from the sensor network with net-based structural models and analysis tools and decision-making tools that allow managers to make informed and optimal decisions on maintenance and upkeep without sacrificing safety and performance. The technology could easily be adapted to other large infrastructure systems such as roads, pipelines, and tunnels. TIP support is needed because of the high aggregate risk of developing and integrating a complex set of new, multidisciplinary technologies.

Development of Rapid, Reliable, and Economic Methods for Inspection and Monitoring of Highway Bridges

The University of Texas at Austin (Austin, Texas, Joint Venture Lead)

- Project duration: 5 years
- Projected TIP contribution: $3,421,000
- Project cost-share contribution: $3,421,000

The joint research venture led by the University of Texas at Austin and including National Instruments Corporation (Austin, Tx.) and Wiss, Janney, Elstner Associates, Inc., (Northbrook, Ill.) plans to develop two related wireless network systems that together address a critical issue for bridge safety, the monitoring of cracks or defects and corrosion in key structural components. One will be a network of low-power, wireless sensors designed to continuously monitor fracture-critical bridges. A second network of passive sensors will be designed to detect early signs of corrosion in reinforced concrete bridge decks. The proposed research involves several major challenges that require TIP support, particularly the extremely long target service life of the sensors and data acquisition systems. The research in this proposal will not only transform the inspection practices used for highway bridges today, but also will dramatically advance the state of the art in wireless sensing technology.

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