Technology Innovation Program

Transforming America's Future Through Innovation

TIP
Technology
Innovation
Program

2009
ANNUAL REPORT

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U.S. Department of Commerce
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We would like to extend our appreciation to the many proposers, **TIP** awardees, and authors of white papers whose creativity, vision, and passion for science and technology is vital to the continued advancement of U.S. leadership in innovation.


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Acting Director's Statement

These are exciting times technologically, and the Technology Innovation Program (**TIP**) is at the forefront in improving America's future competitiveness. In December 2009, **TIP** announced 20 new projects in two areas of critical national need: Manufacturing and Civil Infrastructure. During the active lives of these projects, **TIP** and its awardees will invest $146 million in research and development (R&D) spending, including $71 million projected from **TIP** and $74.6 million in cost-shared funding. In early 2009, the recipients of the nine Civil Infrastructure projects funded during our 2008 competition initiated work, and the initial public response to this research has been extremely positive. We also conducted our first customer satisfaction survey in 2009.

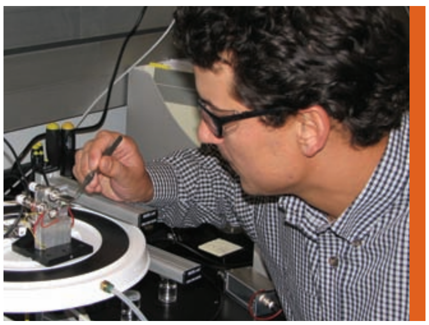
TIP fills gaps within the national research spectrum by providing shared funding to leverage emerging high-risk, high-reward research that has the potential to create transformational impacts on the Nation's critical needs. Whether the challenge is, for example, inspecting the Nation's infrastructure, reducing carbon emissions, or accelerating the emergence of personalized medicine, **TIP** can leverage National Institute of Standards and Technology (NIST) expertise to complement the work of other agencies and broadly engage the scientific, technology, and policy communities to identify key unmet needs within these societal challenges.

I am pleased to have this opportunity to share with you the work that we accomplished in 2009, under Marc Stanley's leadership as Director, in this second **TIP** Annual Report. Marc Stanley led **TIP** from its start to early 2010. He initiated key features of the program, including its emphasis on excellence and integrity, its commitment to the highest standards of scientific achievement, and its outreach to broader communities.

In 2009, **TIP** opened a dialogue with the Nation's scientific community to explore critical national need topics suitable for **TIP** funding and to improve overall program effectiveness. We intensified collaborations with our colleagues in the NIST laboratories and the Hollings Manufacturing Extension Partnership, extended our interactions with other Federal agencies, including the National Science Foundation, the National Institutes of Health, the Department of Transportation, and the Department of Energy, and embarked on a strategic outreach program. We broadly engaged the public by soliciting input on future funding areas, and already have received more than 230 white papers from the various academic and industrial research communities recommending new areas for future **TIP** investment. These communities have commented on **TIP**'s white papers, which were made available on the **TIP** website in November 2009, suggesting possible scope for future solicitations. This enthusiastic support for the program and the positive reception we have experienced are highly encouraging.

I am pleased to report that **TIP** has recruited an outstanding, visionary Advisory Board. This Board met twice in 2009, providing valuable advice on future directions. Additionally, the tireless efforts of the highly competent and motivated **TIP** staff lead me to feel pride and a keen sense of accomplishment as we move forward.

Lorel Wisniewski
Acting Director, Technology Innovation Program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Executive Summary

In 2009, the Technology Innovation Program (**TIP**) continued to focus on identifying and filling gaps in the Federal research spectrum. The program provided resources to leverage emerging research that addresses the Nation's critical needs. These needs challenge society's ability to respond to threats to the Nation's economy, environment, health, and safety. **TIP** addresses these needs by investing in innovative research projects that will develop technologies to solve these problems.

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TIP fulfilled its mission by—

- Making awards to 20 new projects that, have the potential to leverage over their lifetimes will invest $71 million in Federal funds matched with $74.6 million in cost-shared funding.
- Holding competitions in two areas of critical national need, Civil Infrastructure and Manufacturing, which received 138 proposals.
- Initiating the nine projects awarded in the 2008 Civil Infrastructure competition.
- Convening the first meetings of the **TIP** Advisory Board, which provided advice on program directions and discussed potential areas of critical national need including Energy, Healthcare, Manufacturing, Complex Networks, and Sustainability.
- Engaging the broader scientific and technical community by leveraging 42 events to reach that community.
- Receiving more than 230 white papers from more than 500 authors representing more than 300 institutions.
- Publishing draft **TIP** white papers suggesting possible future directions for program solicitations and receiving comments from industry leaders and experts.
- Working with the National Bureau of Economic Research to hold a conference uniting scientists, policy experts, and economists to discuss the Nation's emerging critical needs.
- Surveying the applicants to the 2008 **TIP** competition to identify areas for continuous improvement.

Section 1 of this Annual Report provides a brief background overview of **TIP**. Section 2 describes **TIP's** areas of investment in 2009, Civil Infrastructure and Manufacturing, including ongoing and new awards in those areas. Section 3 describes how **TIP** engages the scientific, technical, and policy communities to obtain information for determining areas for investment. Section 4 describes areas of critical national need under review for possible future solicitations. Section 5 provides an overview of the initial meetings of the **TIP** Advisory Board. Section 6 provides a preliminary overview of **TIP's** plans for impact analysis. Section 7 reports on **TIP's** survey of applicants to its 2008 competition. Appendix A provides abstracts of the projects awarded in 2009. Appendix B provides a brief overview of **TIP**'s competition process and award criteria.

SECTION 1 ▶ What Is the Technology Innovation Program?

The Technology Innovation Program (**TIP**) provides cost-shared funding to speed the development of high-risk, high-reward, transformative research. This research is targeted to key societal challenges that are not being addressed elsewhere.[1] **TIP** is part of the National Institute of Standards and Technology (NIST) headquartered in Gaithersburg, MD. **TIP** is strategically positioned 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 in areas of critical national need. **TIP**'s implementing regulation[2] (**TIP** Rule) defines a societal challenge as "a problem or issue confronted by society that when not addressed could negatively affect the overall function and quality of life of the Nation and as such justifies government attention."[3] **TIP** identifies societal challenges that require transformational technical research to address the underlying problems. **TIP** staff work with agencies across the Federal Government to ensure that **TIP** funds are targeted at those elements of societal challenges not otherwise being addressed.

Program funds can support only research that has scientific and technical merit, as well as strong potential for making state-of-the-art advances and contributing to the U.S. science and technology (S&T) base. The research must carry high technical risks—and commensurate high rewards if it is successful. The mechanism for this support is cost-shared cooperative agreements awarded through merit competitions.

1 TIP was created on August 9, 2007, as part of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES Act), P.L. 110-69.

2 15 C.F.R. Part 296.

3 15 C.F.R. Part 296.2.

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

Features

TIP's major features include the following:

- **TIP has a novel purpose.** TIP awards funding for high-risk, high-reward research and development (R&D) projects that address the Nation's critical needs and societal challenges in areas not being addressed by others. **TIP** has the ability to make targeted investments that are within NIST's areas of technical competence and are outside the current focus of other mission-oriented agencies or programs.

- **TIP supports rich teaming.** Projects may be proposed by individual small or medium-size for-profit companies or by joint ventures that may include for-profit companies, institutions of higher education, national laboratories, nonprofit research institutes, or state or local agencies, so long as the lead member is either a small or medium-size business or an institution of higher education.[4]

- **TIP is a public-private partnership.** TIP makes cost-shared awards of up to 50 percent of total project costs. **TIP** may award up to $3 million

4 Full information on the requirements of TIP joint ventures and eligibility issues for project teaming arrangements can be found on pages 3 to 5 of the *Technology Innovation Program Proposal Preparation Kit, April 2010*, available at *http://www.nist.gov/tip/upload/tip_preparation_kit_2010-_complete_a.pdf*

in direct costs total over 3 years for a single-company project or up to $9 million over 5 years for a joint venture project.

- **TIP supports small and medium-size businesses.** Large businesses may participate in a **TIP**-funded project, but they may not receive **TIP** funding as a recipient or subrecipient.

- **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** staff work with other agencies to ensure that **TIP** competitions are in areas not being addressed by other Federal agencies. In addition, **TIP** works closely with the private sector to understand where private resources are not available.

- **TIP contributes to the U.S. knowledge base.** Title to any intellectual property created through **TIP** funding will vest with the participants in the **TIP** project.

- **TIP is part of the U.S. innovation system.** **TIP**'s purpose is to assist all participants in the innovation system to support, promote, and accelerate innovation in the United States.

- **TIP assesses its progress and results.** TIP uses state-of-the-art evaluation and assessment techniques to ensure optimal performance and results. An external **TIP** Advisory Board provides advice on programs, plans, and policies.

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

Photo Credit: NIST/Robert Rathe

SECTION 2

Addressing the Nation's Critical Needs

In December 2009, **TIP** announced 20 new awards in two areas of critical national need: Manufacturing and Civil Infrastructure. The funded projects represent $71 million of projected **TIP** funding over the life of these awards matched with $74.6 million of cost-shared funding from the project participants. Rich teaming is evident in these projects as nine are joint ventures and many of the single-company projects involve universities as contractors or subrecipients. The 20 funded projects include 38 entities participating as single company leads or joint venture members. These 38 entities are located in 18 states demonstrating the geographic diversity of the interest in these topic areas.

Combining the 2009 awards with prior awards, **TIP** has now awarded 29 projects. These 29 funded projects include 69 entities as single company leads or joint venture members. These 69 entities are located in 22 states. The map in Figure 1 depicts the states in which all single company lead or joint venture member entities in **TIP** projects awarded to date are located.

Over its two years, **TIP** has received 186 proposals involving 325 single company leads and joint venture members located in 39 states and the District of Columbia as depicted in Figure 2. This widespread interest in **TIP's** first two competitions demonstrates the engagement of the technical community with **TIP**.

Figure 1. Location of Single Company Leads and Joint Venture Members in All Awarded TIP Projects

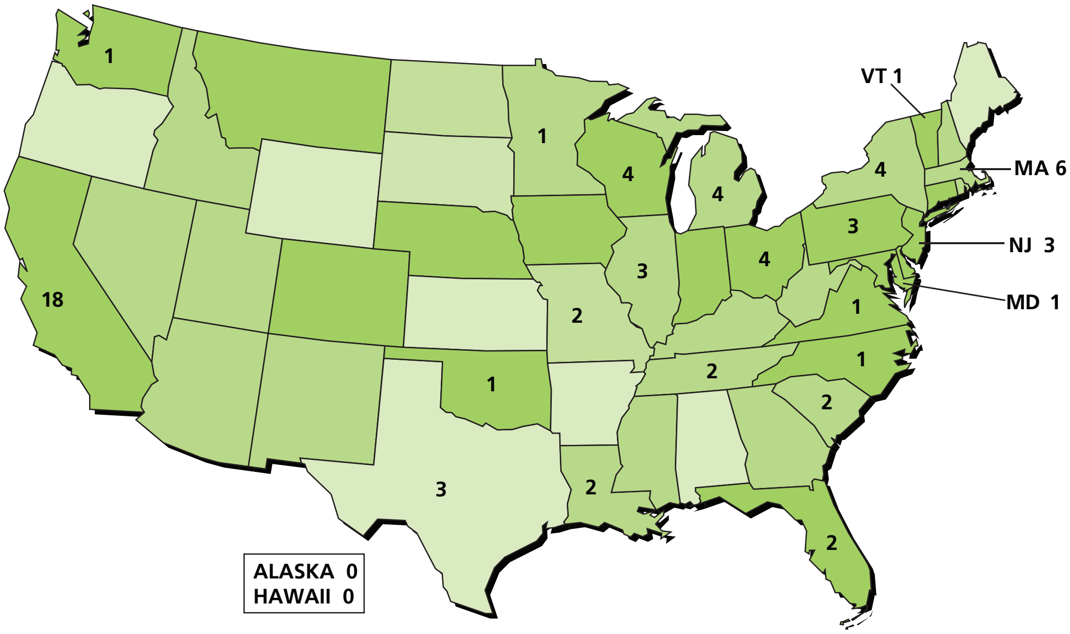
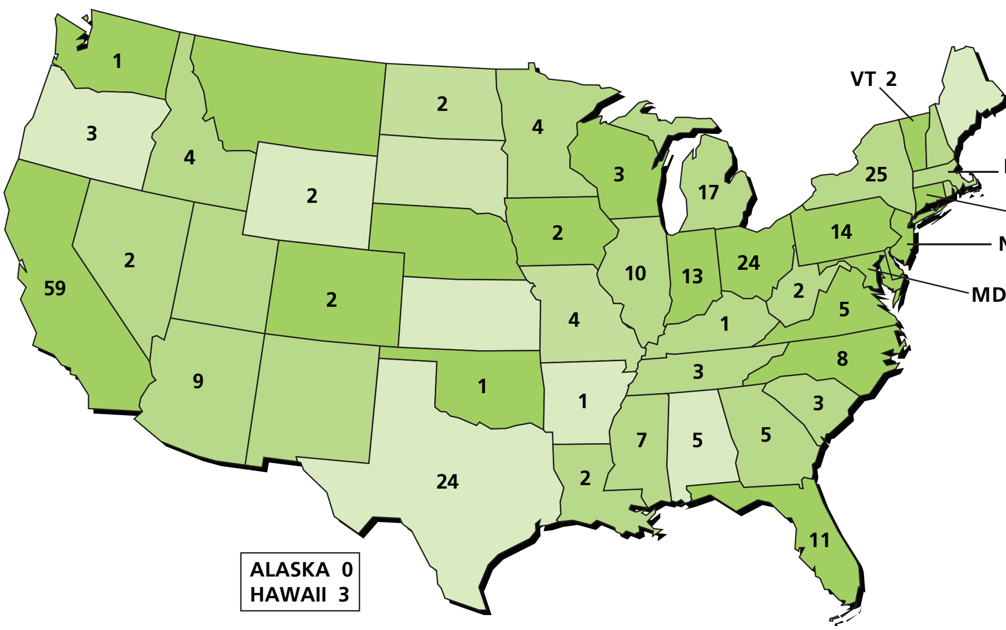


Figure 2. Location of Single Company Leads and Joint Venture Members in All Proposals Received at TIP[5]



New Projects Awarded in 2009

Manufacturing

During fiscal year (FY) 2009, **TIP** announced its first competition relevant to the Manufacturing areas of critical national need. **TIP** received 63 proposals[6] in Manufacturing and awarded 12 projects. Over the life of these awards, these 12 projects will leverage $40.9 million of Federal funds with $42.9 million of cost-share contribution, for a total of $83.8 million invested in research addressing the challenges of manufacturing advanced materials. These projects include four new joint ventures with a total of 12 members and eight new single-company projects. These projects started in February, 2010.

Manufacturing has a rich history and has long been a significant part of the American economy. The United States is the world's leading producer of manufactured goods. The sector leads in innovation, accounting for more than 90 percent of all U.S. patents registered annually.[7] Transformative research often achieves broad national impact only through incorporation into manufactured products. To preserve this element of the U.S. economy, the manufacturing sector will need to continue to implement technology advancements in the coming years.

5 Note that three entities from Wisconsin were participants in a proposal. A fourth entity from Wisconsin became a joint venture member in that project just prior to award.

6 Of the 138 proposals received by TIP in 2009, 25 addressed topics other than Civil Infrastructure or Manufacturing.

7 Jeff Werling, "The Future of Manufacturing in a Global Economy," December 2003.

In 2009, the Manufacturing topic selected was *Accelerating the Incorporation of Materials Advances into Manufacturing Processes.*[8] The solicitation required that proposals address at least one of its two specific subtopics:

- *Process scale-up, integration, and design for advanced materials.* New materials typically are developed in a laboratory setting, and then samples are given to end users for alpha and beta testing. During this testing phase, it can take considerable time and experimentation to understand how the material can be incorporated into a new product in a way that maintains and utilizes its unique functionality. Scaling up from laboratory quantities to larger volumes, integrating these processes together, and then incorporating them into product manufacturing lines is often nonlinear and does not follow straightforward scaling laws, because of the unique functionality that has been designed into the advanced material.

- *Predictive modeling for advanced materials and materials processing.* Predictive modeling capabilities are key to developing new processes, scaling up these processes, and understanding how to utilize an advanced material's unique functionality. Modeling capabilities are needed principally to achieve the following:

    - Analyze and understand why a newly discovered material does what it does and then extrapolate its behavior to new conditions or uses; and
    - Incorporate this knowledge into process design tools so new products can quickly be made while maintaining the unique functionality of the materials.

Transformative research often achieves broad national impact only through incorporation into manufactured products.

Proposed research also was required to apply the technology chosen to at least one of three classes of advanced materials: (1) nanomaterials; (2) composites; or (3) alloys, super-alloys, and smart materials.

This area of focus was chosen because materials performance is often a critical consideration and controlling factor in the innovation process.[9] Nanomaterials are finding their way into better performing batteries, energy storage devices, high-voltage transmission lines, and healthcare applications (e.g., imaging); composites make larger, more efficient wind turbine blades and provide improved performance in aerospace applications; high-strength alloys, aluminum, and magnesium are used to build stronger, lighter, and safer vehicles; super-alloys are used to make higher-efficiency gas turbines; and smart materials hold out promise of combining sensor capabilities in coatings for use in a wide variety of

8 Details of this solicitation topic are available in the Federal Funding Opportunity notice for this solicitation at *http://www.nist.gov/tip/upload/2009_ffo_final1_amendment.pdf*, and the TIP white paper describing this area is available at *http://www.nist.gov/tip/upload/manuf_wp_032009.pdf.*

9 *Integrated Computational Materials Engineering: A Transformational Discipline for Improved Competitiveness and National Security* (Committee on Integrated Computational Materials Engineering, National Research Council, 2008), 1.

applications. Sustainable materials development and materials substitutions are critical to ongoing or increased competitiveness of U.S. innovations.

The selected proposals in Manufacturing addressed both technical areas: process scale-up integration and design (11 projects) and predictive modeling (1 project). All three material types are represented in the 12 projects: nanomaterials (6 projects); composites (4 projects); and alloys, super-alloys, and smart materials (2 projects).[10]

More details on the projects are available in the project abstracts in Appendix A.

Civil Infrastructure

TIP received 50 proposals in Civil Infrastructure and awarded eight new projects. Over the life of these awards, $30.1 million of Federal funds will leverage $31.7 million of cost-share contribution for a total of $61.8 million invested in research to address these problems. These projects consist of five new joint ventures with a total of 15 members and three new single-company projects. These projects started in February, 2010.

Civil infrastructure, the framework of interdependent networks and systems required to provide services and to support social and economic activities, is critical to modern society. As the civil infrastructure ages, the problem of allocating maintenance resources and repairing the infrastructure becomes ever more critical. Inspection and monitoring make up one component of infrastructure management. The need for better tools for infrastructure management is national because every municipality and state in the Nation faces infrastructure management challenges. The need is critical because portions of the infrastructure are reaching the end of their lifespans and few cost-effective technologies are available to monitor infrastructure integrity and prioritize and affect the repair or retrofit of infrastructure elements.

In 2009, the Civil Infrastructure topic selected was *Advanced Sensing Technologies and Advanced Repair Materials for the Infrastructure: Water Systems, Dams, Levees, Bridges, Roads, and Highways*.[11] This topic area continued and expanded on the competition in Civil Infrastructure in 2008, which was titled *Advanced Sensing Technologies for the Infrastructure: Roads, Highways, Bridges and Water Systems*.[12] The 2009 solicitation expanded on

Photo Credit: ©iStockphoto/Justine Latour

10 Proposals are assigned to technical areas and classes of materials based on the primary area and primary class of material addressed in the proposal. Many process scale-up, design, and integration proposals included some work in predictive modeling. Similarly, several proposals indicated plans to move beyond a primary material class to other materials in the future.

11 Details of this solicitation topic are available in the Federal Funding Opportunity notice for the 2009 TIP solicitation at http://www.nist.gov/tip/upload/2009_ffo_final1_amendment.pdf, and the TIP white paper describing this area available at http://www.nist.gov/tip/upload/ci_wp_031909.pdf.

12 Details of this solicitation topic are available in the Federal Funding Opportunity notice for the 2008 TIP solicitation at http://www.nist.gov/tip/upload/tip_2008_ffo_final_7-8-08.pdf, and the TIP white paper describing this area available at http://www.nist.gov/tip/upload/cnn_white_paperfinal.pdf

the scope of the 2008 competition by including repair and retrofit materials as well as application technologies in addition to inspection and monitoring technologies. The strong response from the Scientific and Technical (S&T) community to the 2008 competition as well as the continuing need to address the Nation's aging civil infrastructure led **TIP** to invest additional funds for new awards in this area. The 2009 competition explicitly included dams and levees. **TIP's** vision for this funding opportunity was as follows:

- To develop new tools and techniques that will enable infrastructure managers to monitor the structural health of critical national infrastructure elements that are essential for the health of the Nation, its economy, and its citizens;
- To develop the means to sense the safety, security, and integrity of engineered structures above ground, in ground, and below water surfaces, which are within the Nation's highway, water, wastewater, and water control systems, that provide information to managers of these systems in a time-and-need effective manner; and
- To develop novel advanced materials or novel application technologies that will make repairs or retrofits more economical and extend the usable lifetime of existing civil infrastructure.

The full portfolio of projects in Civil Infrastructure now addresses two technical areas: inspection and monitoring (13 projects) and repair and retrofit technologies (4 projects). These technical areas are applicable to the three application areas: highway bridges (nine projects), highway pavement (two projects), water systems (five projects), and dams and levees (one project).[13]

Civil infrastructure, the framework of interdependent networks and systems required to provide services and to support social and economic activities, is critical to modern society.

More information on the 2009 awarded projects is available in Appendix A. A brief overview of **TIP**'s competition process and criteria is available in Appendix B.

Ongoing Research Projects

For **TIP**'s first solicitation in 2008, **TIP** selected Civil Infrastructure as the area of critical national need to be addressed. The specific solicitation topic was *Advanced Sensing Technologies for the Infrastructure: Roads, Highways, Bridges and Water Systems.*[14] This solicitation focused on inspection and monitoring issues and called for implementable, usable, and accurate sensing systems for the effective measurement of infrastructure performance characteristics, such as fatigue, corrosion, stress, usage, and damage. These new sensing technologies could provide increased security and safety for key elements of critical infrastructure.

13 Proposals are assigned to technical areas and types of infrastructure based on the primary area and primary type of infrastructure addressed in the proposal. Several proposals indicated plans to move beyond the initial technical area or type of infrastructure at some point.

14 Details on the scope of the 2008 competition can be found in the Federal Funding Opportunity notice for that competition available at *http://www.nist.gov/tip/upload/tip_2008_ffo_final_7-8-08.pdf,* and the white paper describing the area available at *http://www.nist.gov/tip/upload/cnn_white_paperfinal.pdf*

Nine awards in this area with a potential for investing $88.2 million (including $42.5 million in Federal funding and $45.7 million in cost-shared funding) over the next 5 years were awarded.[15] Seven of these projects were joint venture projects and two were single-company projects. These projects began work early in 2009 to address three key application areas of inspection and monitoring technology for civil infrastructure: highway bridges (six projects), highway pavement (one project), and water systems (two projects). **TIP**'s project management teams have performed kickoff meetings with project participants, as well as a subsequent annual site visit. In addition, **TIP**'s project management teams perform ongoing monitoring of these projects through quarterly technical and impact reports to ensure compliance with the award terms and conditions and to engage in valuable technical discussion with the project participants. **TIP** proactively identifies and resolves project management issues.

These projects have received substantial interest from local and state Government entities. All nine projects have involvement from public sector entities that are tracking the projects and, in many cases, are committed to providing opportunities for testing. One of the projects, "Cyber-Enabled Wireless Monitoring Systems for the Protection

15 See *http://www.nist.gov/public_affairs/releases/20090106_tip_award_announce.cfm* for more information on these nine projects.

Photo Credit: ©iStockphoto/Maciej Noskowsk

Photo Credit: ©iStockphoto/Joerg Reimann

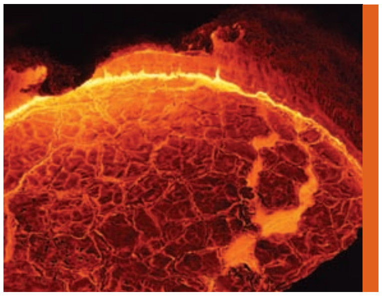


Photo Credit:©iStockphoto/Muzaffer Akarca of Deteriorating National Infrastructure Systems" conducted by a joint venture led by the University of Michigan, received substantial positive response.[16]

SECTION 3 ▶ Engaging the Nation's Scientific, Technical, and Policy Communities

In 2009, **TIP** actively engaged the Nation's technical and policy communities to further **TIP**'s mission to mobilize technical research in support of elements of societal challenges that otherwise were not being addressed. **TIP**'s statutory requirement to address critical national needs requires dialogue between policy communities that have identified emerging societal challenges and technical communities with solutions requiring innovative high-risk, high-reward R&D.

Input from these communities is one part of **TIP**'s approach to defining and selecting areas of critical national need. This contact with technical and policy communities begins with **TIP**'s multifaceted efforts at educational outreach, and was enhanced in 2009 with a National Bureau of Economic Research (NBER)–sponsored conference bringing together policy and technical experts in a variety of critical national need areas. Another part of that outreach was a call for white papers from the scientific and technical communities to help define future critical national need areas for solicitations. The 235 white papers provided in response demonstrated the national interest in this program. **TIP** further extended the dialogue in late 2009 by seeking public comment on four of its own draft white papers. **TIP**'s broad, ongoing engagement with the community is consistent with the Administration's call for transparency in government and will enhance **TIP**'s ability to effectively implement its mission.

> TIP developed a multifaceted, comprehensive outreach strategy to mobilize technical research addressing critical national needs.

The research and policy communities have responded to **TIP** with both white papers and proposal submissions. Authors or contributors from 41 states and the District of Columbia have submitted white papers to **TIP**. Proposals have been submitted that include single company leads or joint venture members from 39 states and the District of Columbia. Many national organizations like the State Science and Technology Institute (SSTI) continue to provide input.

Outreach Efforts

TIP outreach is planned and conducted with several objectives. The first is to provide general information about the program to develop ongoing, robust relationships with other key stakeholders and groups with an interest in research programs such as **TIP**. Another objective is to develop a series of opportunities for input from key stakeholder groups. These opportunities will enable **TIP** to gather input about potential societal challenges, within areas of critical national need that **TIP** should consider for future

16 "Span of Control," *The Economist*, September 3, 2009; "Ten Young Geniuses Shaking up Science Today," *Popular Science*, November 19, 2009; Anna Vander Broak, "Self-Healing Concrete," *Forbes*, November 2, 2009.

competitions. Additionally, outreach efforts focus on explaining to specific technology communities that include potential proposers to ensure that a robust set of proposals are submitted for future **TIP** competitions.

During 2009, **TIP** developed a multifaceted, comprehensive outreach strategy. A combination of webcasts, personal visits, journal articles, conference attendance, conference exhibits, conference poster sessions and presentations, proposers conferences, targeted correspondence, and media coverage was used to provide a general overview of the **TIP** program, to gather input relative to potential societal challenges and areas of critical national need, and to publicize the details of the second **TIP** competition. Target audiences included the various state and local S&T organizations, technical and professional societies, other Government agencies, and academia and industry, especially small businesses.

The **TIP** Director conducted a series of outreach meetings and presentations to key groups identified as being critical to **TIP**, including SSTI, the Society for the Advancement of Material and Process Engineering (SAMPE), the SPIE (an international society advancing light-based research), the Optoelectronics Industry Development Association (OIDA), as well as a variety of state and regional venues. Additional **TIP** outreach was conducted by **TIP** staff, including presentations and exhibits at selected conferences such as the 2009 Materials Research Society (MRS) Spring Meeting, the Renewable Energy World Conference, the Manufacturing Extension Partnership (MEP) National Conference, the Council for Chemical Research (CCR) Annual Meeting, and Biotechnology Industry Organization Conference 2009, as well as invited talks for such groups as the National Council of Entrepreneurial Technology Transfer (NCET2), the Association of University Research Parks (AURP), and the Personalized Medicine Coalition. During 2009, **TIP** exhibited at nine venues, including the National Small Business Innovation Research (SBIR) Conference, Federal Laboratory Consortium, and Minority Enterprise Development Week 2009. Six webcasts were conducted, and **TIP** staff participated in 42 different outreach events during the year. Four proposers conferences were held in spring 2009 at venues across the country in support of the 2009 **TIP** competition announced in March.

Photo Credit: ©iStockphoto/Alexander Raths

The international scientific community expressed interest in **TIP**. During 2009, **TIP** was asked to host or speak to foreign delegations on numerous occasions to explain **TIP**'s features and requirements. **TIP** made presentations to groups from Algeria, Austria, Brazil, Chile, Columbia, Finland, France, Georgia, Germany, India, Ireland, Israel, Poland, the Republic of Korea, Singapore, Spain, and Sweden.

TIP staff produced a number of new documents explaining **TIP**. A significant new addition was an article in the *Journal of Commercial Biotechnology* by Andrew Klein and Mrunal Chapekar, PhD,[17] designed to reach the biotechnology community. Other new additions in 2009 included two full exhibit displays, the 2009 edition of the **TIP** *Proposal Preparation Kit*, the **TIP** *Guidelines and Documentation Requirements for Research Involving Human and Animal Subjects*,[18] and *A Guide for Preparing and Submitting White Papers to the Technology Innovation Program*.[19]

TIP continued to work broadly across NIST to further its outreach. The NIST Public and Business Affairs Office issued several news releases concerning **TIP** to its general mailing list. **TIP** materials and literature were used with the general NIST booth and exhibit at relevant technical conferences. **TIP** was able to join with the NIST laboratories to exhibit at several events, including the 2009 MRS Spring Meeting.

Plans for 2010 include a program of conference exhibiting and presentations targeted at audiences most likely to be interested in **TIP** and to have members who can participate in future **TIP** competitions. These include SSTI, MRS, NCET2, CCR, and a series of technical conferences in technology areas likely to be targeted by one or more potential critical national need topics that are in development. Our plan in 2010 is to continue a robust series of speaking engagements and exhibitions at relevant conferences, as well as to conduct a regular series of webcasts on a variety of relevant topics in support of the overall program, active **TIP** awards, and **TIP** competitions. Additionally, **TIP** plans to conduct the first in a series of **TIP**-sponsored workshops specifically designed around a small number of topic areas to further promote input to be used in refining future competition topics.

> TIP fills gaps within the national research spectrum by providing shared funding to leverage emerging high-risk, high-reward research that has the potential to create transformational impacts on the Nation's critical needs.
>
> *— Lorel Wisniewski, Acting Director Technology Innovation Program*

Connecting with the States

In late 2008, **TIP** and one of its fellow NIST extramural programs, the Hollings Manufacturing Extension Partnership (MEP), initiated a collaborative outreach effort. **TIP** has, since its inception, focused on reaching a broad audience of potential stakeholders. A particular area of emphasis has been state and local economic developers and S&T entities, with goals of informing them and getting their participation and feedback on the program. A partnership with MEP affords **TIP** the opportunity to tap into the extensive networks with small manufacturing businesses that MEP has established in all 50 states through its 59 centers and 440 field offices. By working together, these programs serve mutual interests and more effectively reach out to their overlapping communities.

To this end, **TIP** and MEP conducted a series of regional outreach efforts designed to inform

17 Andrew S. Klein and Mrunal S. Chapekar, "Innovate America: The Technology Innovation Program at NIST," *Journal of Commercial Biotechnology* 15, no. 4 (2009), 293–300.

18 Available at *http://www.nist.gov/tip/upload/has_2009_book.pdf*

19 Available at *http://www.nist.gov/tip/wp/upload/guide_for_white_papers.pdf*

stakeholder communities about the two programs. **TIP** and MEP engaged SSTI and the Council for Community and Economic Research (C2ER) to handle logistics and facilitate the meetings. Beginning in December 2008, through October 2009, **TIP** and MEP conducted four joint regional workshops in Atlanta; San Francisco; Washington, DC; and Kansas City with additional venues under consideration for 2010. These workshops brought together more than 260 attendees from 34 states and the District of Columbia, with about 70 attendees from state and local government or nonprofits, about 40 from academia, and more than 140 from industry. As part of the workshops, **TIP** and MEP held special outreach sessions for state officials to explore ways that state agencies can help these two programs better reach their intended audiences in those states. Twenty-four attendees representing 22 different states participated in these events, and both **TIP** and MEP received excellent input and forged key relationships. As a result of these efforts, some state officials have indicated an interest in obtaining a better understanding of the program to assist potential proposers in their states. **TIP** intends to pursue all such opportunities with state officials as they arise.

National Bureau of Economic Research Conference Summary

On March 2, 2009, **TIP** collaborated with the NBER, the National Opinion Research Center at the University of Chicago, the Alfred P. Sloan Foundation, and the Labor and Worklife Program at Harvard Law School to hold an S&T conference titled "Toward an R&D Agenda for the New Administration and Congress: Perspectives from Scientists and Economists." The purpose of the conference was to identify major societal challenges or opportunities in which S&T was clearly a part of the solution or response. Questions sent in advance to panelists were intended to elicit a cost-benefit analysis presentation to justify R&D in specific technology areas. First, panelists identified major societal challenges or opportunities and areas of critical national need with large potential social or economic impact. The panelists then identified S&T solutions that are most likely to show great promise to be part of an overall answer to the challenge. For each S&T solution proposed, the panelists discussed what kind of R&D program is needed, and what kind of outcomes can be expected within a bounded time frame. Although NBER oriented the conference toward applied solutions and benefits, it also tried to elicit ideas about directions in fundamental science that might have a substantial impact on known national problems.

Conference sessions centered on the following major themes:

- *Baseline: Understanding the U.S. Government's funding of S&T R&D.* This panel, titled "Economics and Policy Perspectives on R&D" discussed the baseline situation with regard to how the Federal Government funds S&T R&D.

- *R&D for new energy technology.* This session centered on fundamental and applied science to achieve energy independence. Key technology areas discussed included the needs of the electric power grid, solar energy, and new battery technologies. The panelists addressed the issue of how government can work with industry and academia to realize new energy technologies.

- *R&D for a sustainable environment.* The session centered on the problems of managing use of the natural environment, natural resources, and the U.S. ecosystem. Panelists discussed how the United States can ensure sufficient supplies of clean water, air, and food, and how it can realize green and smart buildings.

- *R&D for better health.* Panelists discussed how new advances in research can help realize the promise of better health and well-being, including ensuring public health. Topics included biologically inspired engineering, synthetic biology, and emerging infectious diseases such as pandemic flu. The goal is to translate research into positive impacts on health.

- *R&D for better security.* This panel addressed the issue of how science and engineering can make the Nation safer against the threat of catastrophic terrorism. Topics included cyber attacks, biological attacks such as anthrax, and physical attacks such as dirty bombs. A terrorist attack may cause great loss of life, panic, loss of confidence in the Government, and damage to the economy. The panel discussed new research directions that can help prevent attacks and limit the harm should an attack occur.

Twenty-five speakers, across all five panels, came from universities (17 speakers), industry (4 speakers), national laboratories (2 speakers), Government (1 speaker), and nonprofits (1 speaker). The 118 registered attendees, in addition to the speakers, were from Government and national laboratories (46), universities (18), nonprofits (49), and industry (5). Overall, the conference provided critical technical and policy insights for **TIP** staff and provided opportunities for attendees to make important connections for the development of white papers on critical national needs for **TIP**.

Soliciting Public Input

In a *Federal Register* notice posted on December 16, 2008,[20] **TIP** asked interested parties to submit white papers describing an area of critical national need and the associated societal challenge. Parties explained how those needs might be addressed through potential technological developments that fit the **TIP** profile of high-risk, high-reward R&D. In this call for white papers, **TIP** sought information about any area of critical national need, including information to assist **TIP** in further defining several topic areas under development. White papers could describe any area of critical national need of interest to the submitter or could address any of the following topic areas: civil infrastructure, complex networks and complex systems, energy, ensuring future water supply, healthcare, manufacturing, nanomaterials/nanotechnology, and sustainability. These white papers—along with the input from NIST, the **TIP** Advisory Board, other Government agencies, the technical communities, and other stakeholders—have been incorporated into the **TIP** competition planning process.

This analysis provides some insight into the range of input **TIP** received through the white paper process. This analysis looks at the organizations that sent in the first 235 white papers, the states in which those organizations are located, and the general topics described in these white papers. The white papers were received between September 1, 2008,[21] and December 31, 2009.

Figure 3 shows the breakdown of the 527 authors and contributors of the first 235 white papers.

In Figure 3, the 16 authors and contributors affiliated with Government entities included seven from Federal Government entities, six from national laboratories, and three from local government entities. The eleven foreign authors and contributors included four from foreign-located companies, two from foreign nonprofits, four from foreign universities, and one from a foreign national laboratory. Fourteen authors and contributors who did not provide an affiliation are grouped in the category labeled "individual."

Figure 4 shows the distribution of the 314 different entities that the 527 authors and contributors provided as their affiliations. There were a number of entities, especially universities, which had multiple authors and contributors affiliated with them.

20 *Federal Register*, 73, no. 242, Tuesday, December 16, 2008, p. 76339. (73 FR 76339)

21 TIP received a few unsolicited white papers before the official call for white papers. All white papers received are grouped together for analysis.

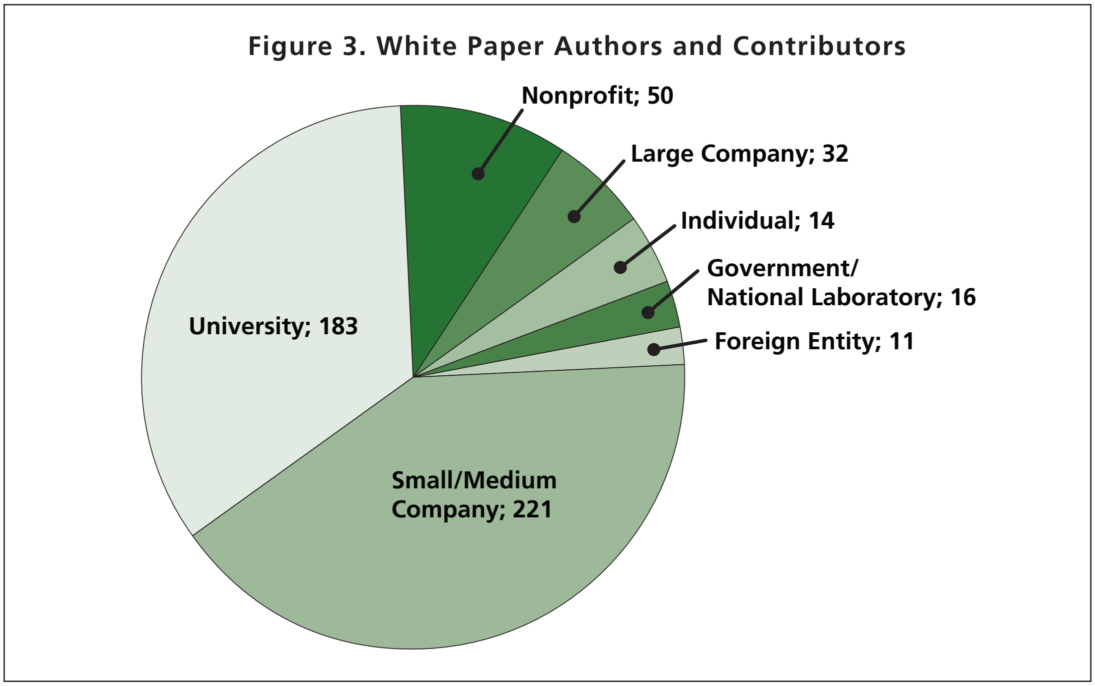


Figure 3. White Paper Authors and Contributors
Nonprofit; 50
Large Company; 32
Individual; 14
Government/
National Laboratory; 16
Foreign Entity; 11
University; 183
Small/Medium
Company; 221

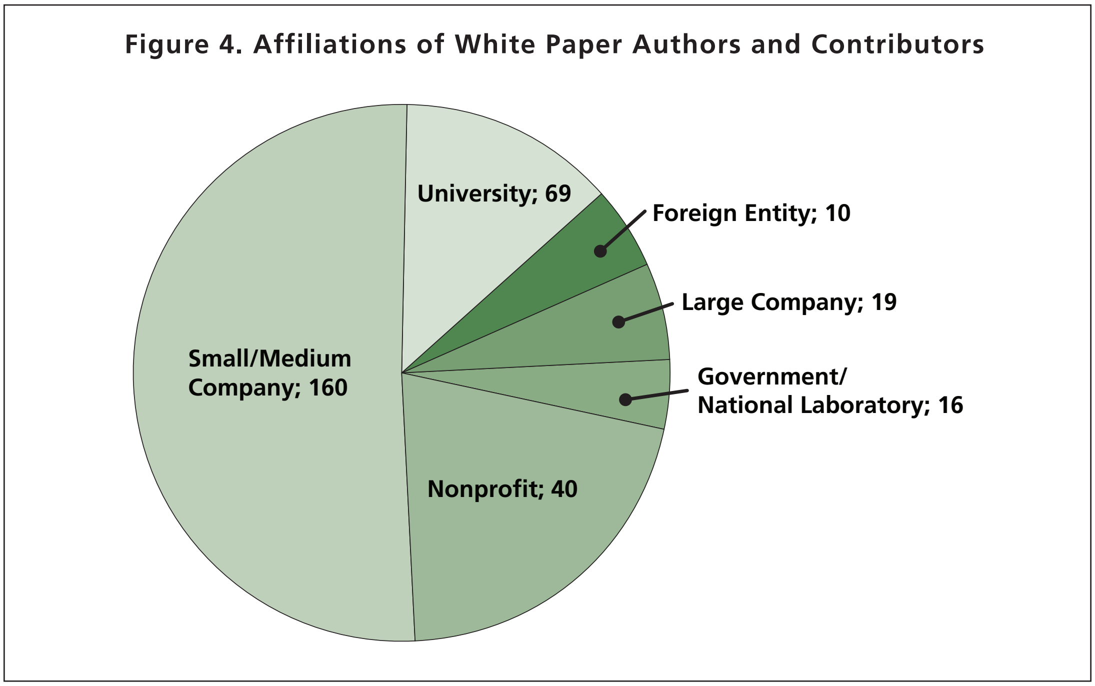


Figure 4. Affiliations of White Paper Authors and Contributors
University; 69
Foreign Entity; 10
Large Company; 19
Government/
National Laboratory; 16
Small/Medium
Company; 160
Nonprofit; 40

Because the paper authors were not asked to classify the entities by type, papers were classified by checking company websites for size information and verifying whether an entity was foreign.

On average, white papers had 2.24 authors. Authorship information follows:

- 140 (or 59 percent) white papers had a single author
- 95 (or 41 percent) white papers had multiple authors or contributors
- 64 (or 28 percent) white papers involved multiple organizations

Sixty-four white papers involved multiple organizations as follows:

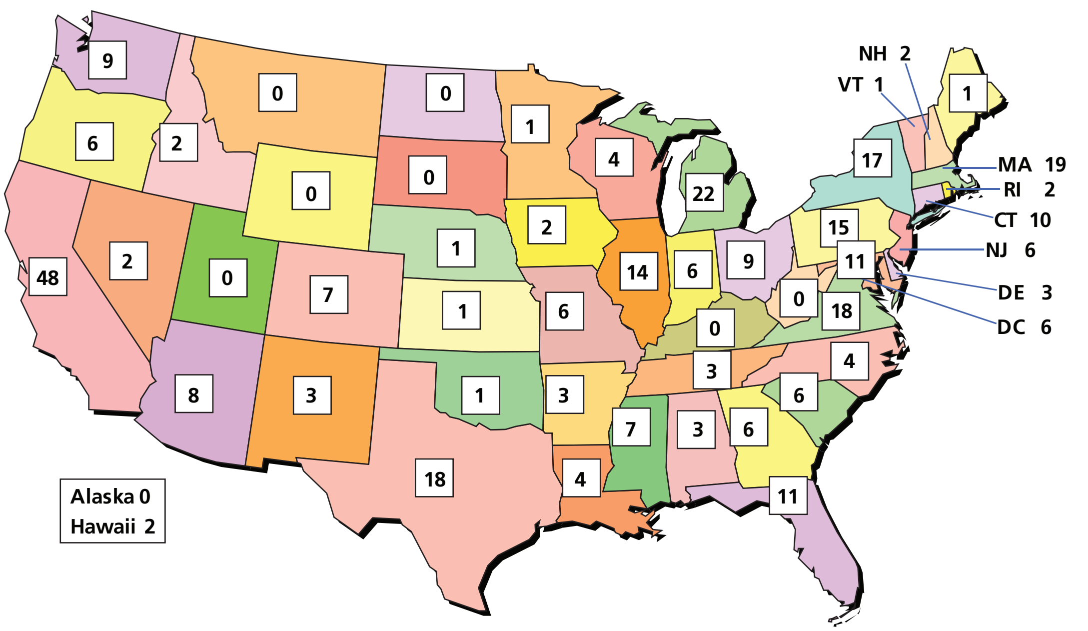
- 33 involved 2 organizations
- 13 involved 3 organizations
- 13 involved between 4 and 9 organizations
- 5 involved 10 or more organizations

Of the 314 organizations that contributed to white papers, 10 were foreign entities. The remaining 304 plus the 14 individuals who did not identify an affiliation came from 41 different states and the District of Columbia. Figure 5 shows the distribution of entities contributing to white papers across the states.

About 78 percent of the white papers (185) included authors or contributors only from one state. Forty-five white papers included authors or contributors from multiple states. Six white papers had only authors from foreign institutions or individuals who declined to identify their home states.

Looking at common configurations of organizations that submitted joint white papers, 19 white papers included at least two small or medium-sized for-profit companies as authors or contributors, and 24 white papers included at least one small or medium-sized for-profit company and

Figure 5. Distribution of White Papers by State



at least one institution of higher education as an author or contributor. Overall, 41 white papers had a combination of entities that could form an eligible joint venture in a **TIP** proposal, thus illustrating a promising mix of organizations that could form eligible joint ventures.

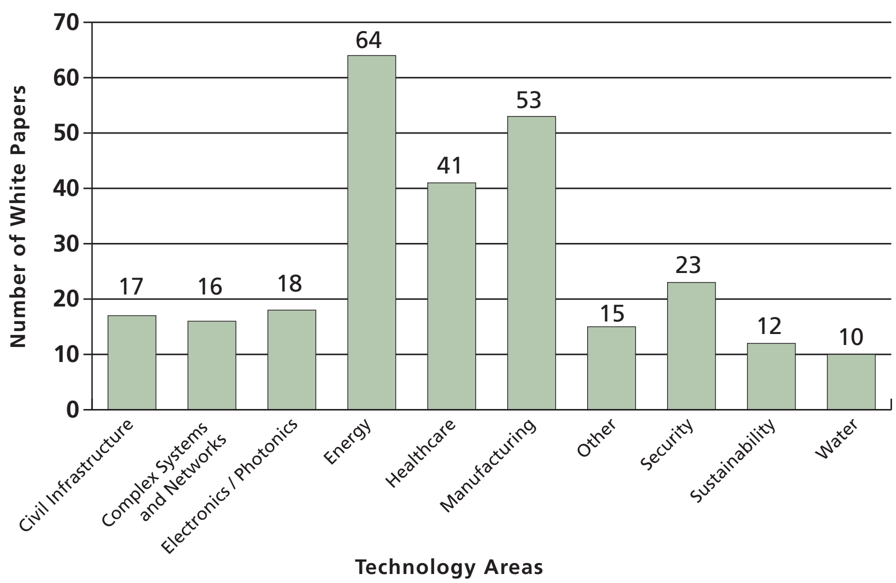
The topic areas addressed in the white papers were frequently cross-disciplinary. Figure 6 categorizes the white papers by the major technology areas addressed in the paper. Papers can be in multiple technology areas.

The manufacturing technology area, cited in Figure 6, includes materials topics and sustainable manufacturing. The healthcare technology area includes personalized medicine and biotechnology. The security technology area includes disaster recovery, cyber security, and voting systems. The other category includes aviation (two), social science (three), education (three), agriculture (one), aquaculture (one), and software development (five).

The following are observations from the white paper solicitation process:

- The white paper process is reaching a large, diverse community of researchers in the United States. This diversity includes both a broad geographic reach and a wide mix of organizations submitting ideas.
- Collaboration has occurred in the development of white papers. This collaboration is internal to organizations and external among different organizations.
- Collaborations that appear promising for future joint ventures may be starting even at the white paper stage. White paper collaborations demonstrate the willingness of companies to work with each other and with universities and other entities.
- Authors invested substantial effort in putting together many of these white papers, demonstrating a significant commitment to the ideas presented in the white papers.

Figure 6. White Paper Technology Areas



Expanding the Dialogue

TIP is continuing to identify areas of critical national need and gaps in the Federal research funding spectrum for technologies that address critical national needs. **TIP** continues working with institutions such as the National Academies, the Science and Technology Policy Institute (STPI), and the NIST laboratories. **TIP** staff continue to evaluate the areas presented in Section 4, "Identifying Areas of Critical National Need," and solicitation topic ideas in these areas remain in development. White papers submitted to **TIP** are analyzed individually and collectively for their contribution to existing areas under evaluation and to identify new areas of critical national need for **TIP** consideration.

On November 6, 2009, **TIP** posted for public comment four of its draft white papers on its website at *http://www.nist.gov/tip/wp/index.cfm*. These draft white papers represent the program's consolidated assessment of critical national needs in these areas as well as associated societal challenges that have a scientific or technical solution. These papers incorporate prior **TIP** research on these critical national need topics, including input received by the time of publication from the NIST laboratories, other agencies, and members of the scientific and technical communities, along with ideas from the many white papers received by **TIP**. The following four **TIP** white papers were posted to the **TIP** website:

- Civil Infrastructure: *Advanced Sensing Technologies and Advanced Repair Materials for the Infrastructure: Water Systems, Dams, Levees, Bridges, Roads, and Highways*
- Energy: *Technologies to Enable a Smart Grid*
- Healthcare: *Advanced Technologies for Proteomics, Data Integration and Analysis, and Biomanufacturing for Personalized Medicine*
- Manufacturing: *Accelerating the Incorporation of Materials Advances into Manufacturing Processes*

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SECTION 4
Identifying Areas of Critical National Need

TIP realizes the program's potential to respond to critical national needs by identifying opportunities to fill gaps or leverage efforts to accelerate innovation within the Federally funded research spectrum. The key to **TIP**'s success is the proficiency with which **TIP** is able to leverage high-risk, high-reward technology to meet unaddressed societal challenges and solve problems concerning critical national needs.

TIP uses a pipeline of critical national need areas and selects topic areas for investment depending on the criticality of the issues and the availability of funding. In developing its critical national need topic pipeline, **TIP** applies consistent measures that allow comparison of different topic areas.

Process Overview

TIP uses a multistage process to establish its pipeline of areas of interest for critical national needs investments for 2010 and beyond. Distinguishing elements of this process are the use of expert opinion at key stages and consistent technology neutral metrics to evaluate different potential topic areas. These metrics are provided below:

- Mapping to Administration Guidance
    - To national objectives
    - To NIST's areas of technical competence
    - To the **TIP** purpose
- Justification 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

TIP's metrics allow the **TIP** Director to systematically evaluate greatly differing areas and challenges and make investment decisions. For example, to address "Mapping to Administration Guidance," **TIP** uses direction from the Office of Science and Technology Policy annual science and technology priorities memo,[22] which lists the Administration's key areas for research investment. The evaluation considers how well the critical national need fits within NIST's areas of technical competence and **TIP**'s purpose of supporting, promoting, and accelerating innovation. In examining the need for Government attention, **TIP** addresses 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 examines the potential for the investment area to stimulate work on scientific frontiers, meet a timely need not met by others (public or private), 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 this gap analysis, **TIP** can

22 See "Science and Technology Priorities for the FY2011 Budget," Memorandum from Peter R. Orszag, Director, Office of Management and Budget; and John P. Holdren, Director, Office of Science and Technology Policy, August 4, 2009, available at *http://www.whitehouse.gov/files/documents/ostp/press_release_files/Final%20Signed%20OMB-OSTP%20Memo%20-%20ST%20Priorities.pdf*

identify specific avenues of research within a critical national need area outside of or complementary to other agencies' focus. To be successful, a program like **TIP** must demonstrate knowledge of what other agencies are doing and show that the programs are complementary.

In 2009, **TIP** examined a variety of input regarding critical national need areas. Potential topics came from white papers submitted to the program, Government agencies' resources and science experts, as well as respected scientific organizations (such as the National Academies), the Science and Technology Policy Institute (STPI), the National Bureau of Economic Research (NBER) conference titled "Toward an R&D Agenda for the New Administration and Congress: Perspectives from Scientists and Economists," industry organizations, leading researchers from academic institutions, the NIST laboratories, and others. **TIP** also leveraged nationally recognized S&T reports, industry roadmaps of technology needs, *An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation*,[23] 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 metrics described above. Some topics were ready for the next stage—that is, preparing a detailed gap analysis and solicitation recommendation—whereas others needed more work. The **TIP** Director used these metrics to select the solicitation topics for 2009 from among the more detailed recommendations.

TIP's metrics allow the TIP Director to systematically evaluate greatly differing areas and challenges and make investment decisions.

Critical National Need Choices and Potential Areas of Interest

Civil Infrastructure—Construction Materials and Processes[24]

The construction industry and its material suppliers generally do not pursue long-term research objectives. The industry focuses on short-term research and development (R&D), which yields modest improvements in products and permits rapid introduction into and acceptance by the marketplace. This short-term R&D focus produces incremental improvements, but it does not allow for the significant advances in construction materials that could revolutionize the industry with superior mechanical and physical properties, higher quality, faster construction time, and reduced maintenance requirements. New materials and process advances are needed to energize the U.S. design and construction industry by providing a competitive advantage through advanced technology and providing tangible economic benefits through market expansion and creation. These developments come from longer-term, high-risk, high-reward R&D that leads to novel solutions that may revitalize and improve the Nation's infrastructure and dramatically increase the

23 Dennis A. Swyt et al., *An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation* (National Institute of Standards and Technology Special Publication No. 1048, 2007), *http://usms.nist.gov/files/USMS-Assessment-Report-2006.pdf*

24 This section represents newly identified societal challenges in civil infrastructure that go beyond the white paper used in defining the 2009 solicitation in civil infrastructure (see pages 6-7) which is the civil infrastructure white paper currently on the TIP website.

Photo Credit: ©iStockphoto/Tor Lindqvist

competitiveness of the U.S. construction industry and its material suppliers.

Next-generation construction materials will need to be substantially more ductile and green than current construction materials, so that future infrastructure materials will have enhanced *durability*, *safety*, and *sustainability*. The next-generation materials and processes could allow the construction industry to move toward structural element production with higher speed, improved quality control, more rapid assembly, and less impact on the environment. These materials and processes would also usher in a more resilient civil infrastructure that would have greater capacity to withstand natural and manmade disasters, with lower maintenance, while increasing service life. This would result in a future built environment in harmony with the natural environment. Focused research on next-generation construction materials and processes will require cross-disciplinary collaboration between material scientists and technologists, experts in material mechanics and design, industrial ecologists, and structural engineers. This next-generation construction material technology will contribute to the Nation's commercial competitiveness while providing better safety, security, and quality of life to its citizens.

Complex Systems and Networks

Our national infrastructure is dependent on such complex networks as those for communications, energy distribution, transportation, and biological systems over which we have imperfect control. No single organization and no collection of organizations has the ability to effectively monitor, analyze, and predict, much less control, society's multiscale, distributed, and highly interactive networks. Most complex system networks are expected to be robust and resilient in their daily functions. When stressed, however, they may respond in unpredictable and harmful ways. Examples include the following:

- *Communications Networks:* assurance of uninterrupted, secure, and fast electronic communications (for example, cyber infrastructure, terabyte networks, security, or interoperability)
- *Energy Distribution Networks:* an electric power grid that is capable of matching energy supply, demand, and distribution for all modes of use under real-time event conditions
- *Transportation Networks:* efficient traffic flow, multimodal transports, minimal energy use, maximized public safety, maximized commerce, and social productivity
- *Biological proteomic networks:* embody problems in pervasive ad hoc networks

The current technical and mathematical methodologies that underpin our ability to simulate and model physical systems are unable to sufficiently predict (much less control) the behavior of complex systems when they are stressed. To

(1) build our knowledge and understanding, and (2) improve our ability to predict failure pathologies, the Nation will require the ability to accurately observe, analyze, learn, and predict complex system behaviors under stress. Therefore the objectives of the program are as follows:

- Overcome limitations of the current tools for understanding complex systems by creating a paradigm shift in the Nation's ability to observe, understand, predict, and affect failure modes in complex systems

- Develop observation and learning platforms for complex systems that enable a structured scientific approach to the understanding and prediction of failure pathologies within complex systems

Energy

TIP has identified energy as an area of critical national need and the smart grid as a specific challenge that could be addressed in a future competition. There is an emerging consensus on the components required to achieve an active smart grid and an identifiable number of key challenges that are essential to a full smart grid operation. These challenges include energy storage and the seamless integration of stored energy into the grid system, advanced sensors with independent energy sources, system and control technologies, and high-voltage power electronics. **TIP** has done a detailed gap analysis in cooperation with DOE identifying areas where **TIP**'s could fill unmet needs

Energy storage: Electrical storage for the smart grid integrates and addresses three requirements that involve diverse operational time scales:

- *Power quality:* response times of less than one-tenth of a cycle ensuring continuity of quality power

Photo Credit: ©stock.xchng/Ivan Prole

- *Bridging power:* response load support times of seconds to minutes ensuring continuity of service when switching from one source to another

- *Energy management:* response load support times of hours for decoupling the timing of generation and consumption

A variety of energy storage systems are available today, but these have limited application to the grid system storage because of low power limitations, low energy density, or high cost. New technologies are needed that will provide fast response time, increased reliability, improved benefit-cost ratio, higher capacities, and improved ability to integrate with high-voltage power electronics (i.e., greater than 10,000 volts [10kV]).

Advanced sensors: Grid security and monitoring systems will require multiple sensors distributed along transmission lines and along all significant grid components, including transformer, capacitors, switches, and breakers. These systems must provide data processing and communications capabilities operating independently of the grid power, while monitoring and reporting on the state of the grid in real time.

System and control technologies: Measurement needs for the smart grid fall into two categories:

- *Performance and efficiency:* new measurements will be needed to evaluate the state, or condition, of the grid. These will indicate the most efficient configuration of the grid and the most appropriate measurement to demonstrate that the grid has achieved a designated performance level.
- *Fine scale measurements:* accurately measure phase angle and frequency of the power on the grid over widely separated points. Subtle shifts in phase angle or frequency of power on the grid can lead to serious stresses and damage to major grid components. High-accuracy measurements of phase angle between distant points on the grid require sensors to be precisely synchronized.

High-voltage power electronics (greater than 10 kilo-volts [kV]): Power electronics is a key technology for interconnecting renewable energy generation to the grid, while providing ancillary services such as reactive power compensation, voltage and frequency regulation and improved power quality and reliability. High-voltage power electronics (operating above 10kV) employs the use of switching devices to control and convert electrical power from one form to another, and are responsible for delivering electricity to the grid.

TIP's draft white paper on this topic, titled *Energy: Technologies to Enable a Smart Grid*, was made available for comment on TIP's website as of November 6, 2009.[25]

Healthcare

Affordable and effective healthcare is an important element of the Nation's quality of life and central to its future growth. Yet escalating healthcare costs are a significant problem. Annual per capita healthcare spending in the United States is high and rising ($7,062 in 2006 and $7,421 in 2007),[26] and currently approved drugs do not always work for the entire population. Physicians typically do not have the clinical information needed to select optimal drug treatments and dosages on the basis of a patient's unique genetics, physiology, and metabolic processes, which can result in a certain amount of trial and error in treatment.

Given the significant advances made and the large amounts of data generated through the pioneering Human Genome Project led by the National Institutes of Health (NIH) and the Department of Energy (DOE), and other Federal programs such as "Tools for DNA Diagnostics" program funded by the former Advanced Technology Program at NIST, the field of personalized medicine is attempting to unlock the important 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. Although the advances in understanding genetic variability have raised high hopes for a new era in the prevention and treatment of disease, major challenges remain in understanding complex biological systems in wellness and disease states. Understanding the connection between genetic and proteomic variations and disease states could provide earlier and more accurate diagnosis and targeted treatment.

25 Available at http://www.nist.gov/tip/wp/upload/energy_wp_11_5_09.pdf

26 Centers for Medicare and Medicaid Services, U.S. Department of Health and Human Services, "National Health Expenditure Data," available at www.cms.hhs.gov/NationalHealthExpendData/02_NationalHealthAccountsHistorical.asp#TopOfPage.

The wellness and disease states also result from a complex interaction between an individual's genetic makeup and the influence of such environmental factors as diet, exercise, exposure to toxins, and drug intake. With these Federal investments, data resources such as genomic and proteomic databases and technologies are being developed to measure environmental toxins, dietary intake, and physical activity of individuals. To recommend preventive measures and safe and effective treatments, an integrated analysis of different data sets will be required. Such analysis may necessitate combining data from disparate databases, such as genomic, epigenomic, toxicogenomic, and proteomic databases, and linking it to patient-specific data such as nutrition, diet, and exercise, in order to lead to earlier and more accurate diagnosis and targeted treatment.

At this time, the manufacturing of biopharmaceuticals is complex and costly, and is based on a large-scale process involving batching and frequent sampling to monitor the quality and safety of the production system. Personalized medicine requires multiple smaller size volumes of patient-specific biopharmaceuticals, and thus needs a change in the biomanufacturing paradigm. Key enabling technologies are needed for automated high-throughput and cost-effective biomanufacturing processes that can simultaneously produce multiple safe, effective and affordable patient-specific biopharmaceuticals. **TIP**'s proposed topic emphasizes three societal challenge areas under the critical national need area of healthcare:

- Understanding of real-time protein interactions noninvasively in complex biological systems will enable real-time noninvasive tracking of cells and cellular molecules in living tissues and systems.
- Integrated analysis of multiple factors allowing linking of personal molecular biology to the environmental triggers necessitates combining data from disparate databases, such as genomic, epigenomic, toxicogenomic, and proteomic databases, and linking the data to patient-specific data, such as nutrition, diet, and exercise.
- Cost-effective manufacturing of diagnostic and therapeutic products is necessary for the success of personalized medicine.

TIP currently is discussing these topics with NIH and other Federal agencies. **TIP**'s goal is to work with Federal and nonFederal groups to further understand research gaps in these areas and to define a complementary and nonduplicative role for **TIP** to address the societal challenges in healthcare and personalized medicine.

> Affordable and effective healthcare is an important element of the Nation's quality of life and central to its future growth.

TIP's draft white paper on this topic, titled *Advanced Technologies for Proteomics, Data Integration and Analysis, and Biomanufacturing for Personalized Medicine*, was made available for comment on **TIP**'s website as of November 6, 2009.[27]

Manufacturing "Advanced Automation"[28]

Manufacturing is an area of critical importance to the Nation and its economy. The manufacturing sector represents the largest of the United States' private industry sectors, supporting more than 14 million jobs and accounting for almost 12 percent of GDP in 2007.[29] The societal challenge "Robotics and Intelligent Automation" within the critical

27 Available at *http://www.nist.gov/tip/wp/upload/healthcare_wp_11_5_09.pdf*

28 This section represents newly identified societal challenges in manufacturing that go beyond the white paper used in defining the 2009 solicitation in manufacturing (see pages 4-6) which is the manufacturing white paper currently on the TIP website.

29 Statistical Abstract of the United States, 2009, Table 964, *http://www.census.gov/prod/2008pubs/09statab/manufact.pdf*

Photo Credit: ©iStockphoto/Rainer Plendl

national need area of Manufacturing has the potential to affect other important areas, including healthcare and homeland security. Input regarding potential societal challenges was obtained from Government agencies, advisory bodies (such as the National Research Council, National Academy of Sciences, and National Academy of Engineering), STPI, industry organizations, leading researchers from academic institutions, and others.

The U.S. manufacturing sector faces enormous challenges from a global economy. Large-volume manufacturers such as automotive, semiconductor, and appliance manufacturers can and have benefited from robotics and intelligent automation[30] to achieve greater productivity, quality, and economy of scale. However, these advantages have been slow to trickle down to small and medium manufacturers owing to a number of factors, including high overhead costs, complexity of setups, and a lack of sufficient flexibility and agility. Furthermore, the robotics industry is in its infancy, is fragmented, and each new application-specific solution basically restarts the design process.

In talking with leaders in the robotics community, the need to support infrastructural-like technologies has been identified as a high priority need. For these technologies to advance, high-risk, high-reward research and development will be needed in areas such as the following:

- Navigation and 3-D planning (the ability to move with people and in work environments)
- Power and energy systems (the ability to work for 8+ hours without a power cord/tether)
- Concurrency (networking and cross-communications)
- Safety and human-robot interaction (the ability to work with people without injuring them)
- Cooperation between different system components (integration that is easy and flexible)

TIP support of robotics and intelligent automation would address a societal challenge within the manufacturing research arena, in addition to having benefits to other industry sectors and areas of critical national need.

Sustainability

Sustainability, according to a widely used definition, is "meeting the needs of the present generation without compromising the ability of future generations to meet their needs."[31] Sustainability is a complex and highly interdisciplinary endeavor with economic, environmental, and societal dimensions. The opportunity for **TIP** is to assist in the development of technologies that reduce or eliminate the environmental "footprint" of industrial processes and public waste streams.

Current domestic consumption of materials and chemicals produces large amounts of waste and is based on finite resources, and many of these

30 For this discussion, robotics and automation are defined by the Institute of Electrical and Electronics Engineers' Robotics and Automation Society: *Robotics* includes intelligent machines and systems used, for example, in space exploration, human services, or manufacturing; *automation* includes the use of automated methods in various applications (for example, factory, office, home, laboratory automation, or transportation systems) to improve performance and productivity. More information available at http://www.ieee-ras.org

31 United Nations, *Report of the World Commission on Environment and Development: Our Common Future*, available at http://www.un-documents.net/wced-ocf.htm

materials critical to our economy must be sourced from areas of geopolitical concern. For example:

- Although industry has made tremendous strides in transitioning to cleaner, safer chemical products (for example, the phaseout of chlorofluorocarbons or CFCs), in 2008 almost 4 billion pounds of toxic material were disposed of or released to the environment in the United States.[32]

- In 2008, the United States emitted more than 7 billion metric tons of greenhouse gases when measured in carbon dioxide equivalents.[33]

- Every year, 25,000 pounds of new, nonfuel minerals must be provided for every person in the United States.[33]

With the assistance of government agencies and nationally recognized scientific organizations (such as the National Research Council, the National Academy of Sciences, and the National Academy of Engineering), STPI, industry organizations, leading researchers from academic institutions, and others, **TIP** has begun to identify some of the societal challenges associated with addressing the critical national need of sustainability:

- *Chemicals Production through Metabolic Engineering*—To develop bio-based process technologies that
  - reduce the consumption of petroleum resources;
  - reduce waste byproduct streams, including emissions; and
  - provide safer pathways for the production of high value-added chemicals.

- *Critical Minerals Availability*—To develop new process technologies that improve domestic capabilities to recover, recycle, and provide substitutes for limited-resource materials such as platinum-group metals, rare earth elements, indium, and manganese.

In addition, **TIP** continues to evaluate challenges that address elements such as cost-effectiveness, energy efficiency, recyclability, safety, resource use, life-cycle analysis, and ecosystem health.

Water

Everyone needs clean water for all phases of daily life. Thus, the need for advanced technologies for better managing water quality is both *national* and *critical.* Water supply is a complicated matter. Freshwater quantity at any particular location and time depends on climate and the dynamics of the movement of water through the hydrosphere. The desired outcome is to develop improved means for better management of the quality and quantity of delivered-water supplies and to protect the public from waterborne-disease sources.

Current sensing technologies for the detection and identification of pathogenic and chemical toxins, while well developed in controlled laboratory environments, have not yielded tools for producing real-time, in situ data for routine use in the food distribution chain or for multiple-site deployment in municipal water systems. Environmental issues associated with concentrated brine discharge from reverse osmosis plants limit deployment, as permitting is a major constituent of the fixed costs of current desalination projects. The energy costs of new means to produce water and treat wastewater need to be reduced to decouple water prices from energy prices and availability. Just as energy prices enter into national economic pressures, so too will water prices as security and scarcity affect the cost of delivered water. The following societal challenges are critical to maintaining the water supply necessary for the Nation:

- *Water Quality—Disinfection and Decontamination:* Disinfection and

32 U.S. Environmental Protection Agency, *Toxics Release Inventory Reporting Year 2008 National Analysis: Summary of Key Findings*, available at *http://www.epa.gov/TRI/tridata/tri08/national_analysis/pdr/TRI_key_findings_2008.pdf*

33 National Research Council, Minerals, Critical Minerals and the U.S. Economy, 2008

decontamination of water before distribution are essential to meet current and future water-quality standards. As the list of regulated substances grows, and as regulated contaminant levels drop, current disinfection and decontamination technologies face serious challenges and will require significant technical advances to meet future needs.

- *Water Quantity—Reclaimed Water and Desalination:* As water demand grows and as regions undergo long-term climate changes, societal challenges to supplement freshwater sources are increasing. At least three means are related to relieving pressure on local water supplies: conservation, reclamation of wastewater, and desalination of brackish water or seawater. The costs of water reclamation are currently prohibitive for widespread usage as a supplement to domestic water supplies.[34] The economics of water reclamation depend not only on the water purification technology but also on disposition of the residual material left after water removal. Because reclamation of wastewater and conservation both depend on an initial supply of water, which may decline or disappear for some communities, desalination of brackish water or seawater must also be considered for communities whose future water supply needs are projected to exceed available freshwater supplies. Significant technical barriers to desalination deployment include the uncertainty regarding the environmental impacts of the disposal of the concentrated brines that result from desalination and the potential for aquatic biota to be harmed by water intakes.

- *Resource Recovery from Wastewater:* Municipal wastewater streams contain significant unrecovered energy and chemical resources. New technologies are needed to cost-effectively derive from waste biosolids an energy stream, such as hydrogen, natural gas, or some other energy carrier. Better technologies are needed for recovery of phosphorous from both the discharged water and the solids portion of the waste stream. A particular challenge for phosphorous recycling technologies is the removal of heavy metals from the produced phosphorous product. Ultimately, municipal waste could become an economic resource.

34 National Institute of Standards and Technology, *An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation* (NIST Special Publication 1048), available at *http://usms.nist.gov/files/USMS-Assessment-Report-2006.pdf*

Photo Credit: ©iStockphoto/David Orr

SECTION 5
TIP Advisory Board

The **TIP** Advisory Board was established by statute with the creation of the program in the America COMPETES Act.[35] The Board includes leading experts on science, technology, and innovation from industry and academia. The statute defines the purpose of the **TIP** Advisory Board as providing the following to the **TIP** Director:

- Advice on programs, plans, and policies of **TIP**;
- Reviews of **TIP**'s efforts to accelerate the R&D of challenging, high-risk, high-reward technologies in areas of critical national need;
- Reports on the general health of the program and its effectiveness in achieving its legislatively mandated mission; and
- Guidance on investment areas which are appropriate for **TIP** funding.

The Board provides its advice both to **TIP** management and to Congress through transmittal of an annual report to the Secretary of Commerce for transmittal to the Congress, as outlined in the **TIP** statute. The Board's first report was published in February, 2010.[36]

In its first year of operation, the **TIP** Advisory Board met on July 7 and December 8, 2009. The 2009 **TIP** Advisory Board members were as follows:[37]

Mr. Jeffrey P. Andrews (chair)
Senior VP, Strategy and Business Development, Advanced Electron Beams

Dr. Vinton G. Cerf
Vice President and Chief Internet Evangelist, Google, Inc.

Dr. Charles L. Cooney
Professor of Chemical Engineering and Faculty Director, Deshpande Center for Technological Innovation, Massachusetts Institute of Technology

Dr. Mauro Ferrari
Professor and Director of the Division of Nanomedicine and Professor of Internal Medicine, The University of Texas

Dr. Martin Izzard
Vice President and Director of the Digital Signal Processing Solutions Research and Development Center, Texas Instruments Incorporated

Dr. Ray O. Johnson
Senior Vice President and Chief Technology Officer, Lockheed Martin Corporation

Dr. Radia Perlman
Fellow, Intel Laboratories

Dr. Luis M. Proenza
President, The University of Akron

Mr. James E. Reeb
Director of Manufacturing, Caterpillar, Inc.

Dr. William Peter Teagan
Independent Consultant

The emphasis at these meetings was to seek advice from the Board on program directions and to discuss potential areas of critical national need. The Board considered Energy, Healthcare, Manufacturing, Civil Infrastructure, Complex Networks, and Sustainability as potential areas. The Board emphasized that interdisciplinary technical areas and interfaces between agency programs represent promising areas of opportunity for **TIP**. To be successful, a program like **TIP** must demonstrate knowledge of what other agencies are doing and be able to show that the

35 America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES Act), P.L. 110-69.

36 Available at *http://www.nist.gov/tip/adv_brd/upload/tip_advisory_bd_annual_rpt_2009.pdf*

37 More information on the TIP Advisory Board members is available at *http://www.nist.gov/tip/adv_brd/members.cfm*

programs are complementary. The Board found **TIP**'s work with other agencies encouraging and a good opportunity to leverage S&T expertise across the Federal government.

At its second meeting, the Board discussed **TIP**'s broader role in the Nation's S&T community and also considered internal program developments, such as collaborations between **TIP** and MEP and the strengthening of the ties between **TIP** and the NIST laboratory programs. The Board reviewed **TIP**'s structure to develop evaluation and assessment techniques and metrics for success and reviewed preliminary results from **TIP**'s first customer satisfaction survey (see Section 7, "Customer Satisfaction Survey").

SECTION 6 ▶ Impact Analysis of Funded Awards: Measuring Program Results

Measurement of program results is an important priority for **TIP**. Not only is this effort consistent with the Administration's emphasis on evaluation, communication, and transparency in government, but it is essential to ensure that **TIP** remains true to its mission and responsive to its stakeholders. **TIP** established its Impact Analysis Group within its headquarters office in early 2009 to lead and coordinate evaluation and assessment efforts across **TIP**.[38]

The goal of impact analysis is to understand the value to the Nation of the results of the **TIP** projects. **TIP** engages in evaluation to comply with its statutory requirements, to address stakeholder requests for program results, to use as a management tool for continuous improvement, and to understand **TIP**'s contribution to the innovation process. In its role of rigorous and independent evaluation, **TIP** examines whether the program is achieving its intended outcomes through strengthening **TIP**'s operations and studying alternative approaches for achieving outcomes to determine which strategies are most effective.

38 TIP's assessment effort builds on the successful evaluation work conducted by the former Advanced Technology Program (ATP). For a synopsis of the ATP evaluation legacy, see Stephen Campbell, Stephanie Shipp, Tim Mulcahy, and Ted W. Allen, "Informing Public Policy on Science and Innovation: the Advanced Technology Program's Experience," *Journal of Technology Transfer* 34 (2009), 304–319.

In developing its evaluation process, **TIP**'s Impact Analysis Group worked with the following organizations during 2009:

- The National Bureau of Economic Research (NBER) in developing metrics and areas of research
- Other agencies charged with evaluation, including the National Science Foundation through its Science of Science and Innovation Policy initiative
- The National Opinion Research Center at the University of Chicago, which hosts a data enclave[39]
- The Volpe Center at the Department of Transportation

TIP is committed to working with the evaluation community and to adopting best practices in evaluation.

TIP Performance Metrics

TIP measures outputs as short-run indicators of progress toward program goals. **TIP** measures outcomes in the longer run to assess the program's impact.

Each year, **TIP** estimates the following performance results as measures of key outputs and indicators of progress in meeting short-run program goals:

- Number of **TIP** projects funded
- Evidence of fostering research collaborations
- Patents, papers, and publications developed through the **TIP** projects that accelerate the creation and dissemination of knowledge

These performance measures are included in NIST's budget submissions to the U.S. Department of Commerce (DoC) and the Office of Management and Budget.

Measuring performance allows **TIP** to achieve the following:

- Track performance over time to assess whether goals are being met
- Link performance to program budget decisions
- Address management challenges

In addition to compiling actual performance results at the end of a given fiscal year, **TIP** forecasts results for the following three years. These forecasts currently are based on historic data from similar R&D programs. The ratio of actual total outputs for a given measure to the cumulative number of completed projects is calculated and applied to the anticipated number of completed **TIP** projects at each future date. The DoC uses the forecasts to generate annual performance targets.

Table 1 shows the **TIP** targets[40] for FY 2009–2012 that the DoC will use to assess actual performance and budgets.

The results and targets shown in Table 1 are based primarily on the following:

39 The researchers are using historical data from the ATP to study the impact of public-private partnerships in scientific research. This collaboration allows TIP to learn from these data and to work with the academic research community advancing the state-of-the-art evaluation methodology.

40 Targets were estimated by TIP in mid-FY 2009. Targets for FY 2010 include a 2009 competition and a projected 2010 competition. Targets are subject to change due to fluctuations in future budget projections. Actual results for a given year are compiled and become available for reporting purposes by the middle of the following year. With the exception of "cumulative number of projects funded," the measures are lagged and will not generate results until three or more years of project research.

- iEdison[41] reporting
- **TIP** portfolio of project participants
- Historic data from similar R&D programs

Additional Notes about Individual Performance Measures

Cumulative number of projects funded: This measure reflects the number of projects funded to support areas of critical national need. Participating organizations include small and medium-size companies, institutions of higher education, national laboratories, nonprofit research institutes, and other organizations.

Cumulative number of publications: This measure reflects scientific knowledge being generated from the funding. Publications include academic journals, conference proceedings, and other publications. The measure also reflects the dissemination of the science benefiting other organizations outside of the project participants. Projections are based on historic data from similar R&D programs estimated at three publications per completed project. The measure is a lagged measure and assumes that publications will be generated by the third year of project research.

Cumulative number of patents applications: This measure reflects an additional metric of valuable knowledge and science generated from the funded research. Projections are based on historic data from similar R&D programs estimated at two patents per completed project. The measure is a lagged measure and assumes that patent applications will be generated by the third year of project research. The iEdison system is the primary means for reporting invention disclosures and patents arising from **TIP**-funded projects.

Cumulative number of projects generating continued R&D: This measure reflects the creation of transformative research whose value is demonstrated by continued R&D investment by the original researchers or by others. The measure is a lagged measure and is assessed after the **TIP** funding has stopped (generally three years or later).

Cumulative number of projects with technologies under adoption: This measure reflects the implementation of the R&D efforts to benefit end users. Adoption includes testing of the research results at a beta site, licensing the technologies to others, using new research methods in performing research, or commercializing the technology through improved products and processes. The lagged measure is assumed to be realized near the end of the project at the earliest (generally three years or later).

Impact Analysis Reporting System

During 2009, **TIP** conducted preliminary development work on a new reporting mechanism for tracking the impact of the research from funded projects. **TIP** expects to require single-company project leads and all members of a joint venture to report individually at the start of the project, annually during the project, and at the conclusion of the project on the inputs to the project research, the progress of the project toward its intended impacts, and the project's outcomes.

The inputs to the project research include preexisting intellectual property, formal and informal contributions of money and other resources, and collaborations that strengthen the project. During the project, impact reporting may include collecting information on potential contact with early adopters

41 iEdison (www.iedison.gov) is a system hosted at the National Institutes of Health that 18 Federal agencies use to track new inventions and associated patents developed using Federal funds. TIP grant recipients must record in iEdison their inventions developed on Federal funds by providing invention disclosures. If the recipient pursues patent applications and, eventually, patents arising at least in part from these inventions then these also must be recorded in the iEdison system.

Table 1. TIP Performance Targets, FY 2009–2012

Performance Measure	Actual FY 2009	Actual FY 2010	Target FY 2011	Target FY 2012
Cumulative number of projects funded	9	29		
Cumulative number of publications	0	0	0	27
Cumulative number of patents applications	0[42]	0	0	18
Cumulative number of projects generating continued R&D	0	0	0	0
Cumulative number of projects with technologies under adoption	0	0	0	0

of the research results as well as identification of the downstream plans for the research to achieve its intended impact. Outcomes of the project include traditional measures such as patents (reported through iEdison), publications, and presentations as well as graduate student theses, knowledge transferred through seminars and courses, and the research foundations for new products and processes. Outcomes data can be further analyzed through the use of bibliometric measures to assess the significance of the body of work coming from a project.

Single company leads and joint venture members will report their information through an online secure Web form directly to **TIP**.

SECTION 7▶ Customer Satisfaction Survey

TIP engages organizations that can contribute cutting-edge research to address the Nation's critical needs. Future success of the program will require effectively engaging and communicating with organizations that may become future proposers. **TIP** will need to understand the extent to which new organizations are being reached and whether past communications are reaching potential proposers and resulting in action.

TIP needs to reach potential new proposers while remaining sensitive to the time and money burden associated with preparing a proposal. This is a particular issue for organizations whose research agenda is unlikely to meet **TIP**'s requirements regarding high-risk, high-reward research. **TIP** always will require that organizations submit proposals that allow the program to carry out its due diligence in awarding taxpayer money. At the same time, **TIP** seeks to better understand, and potentially mitigate, administrative burdens associated with submitting proposals.

In pursuit of these goals, **TIP** worked with the survey firm Westat to develop and field the **TIP** 2008 Customer Satisfaction Survey. The survey was addressed to organizations and individuals from the **TIP** mailing list. Those on the mailing list proactively signed up to receive information and updates

42 One invention disclosure was recorded in iEdison during FY 2009 for a TIP project, but a patent was not pursued in FY 2009.

from TIP regarding current and future award competitions. The survey was designed to answer three broad questions about TIP's application process:

- How effective is TIP outreach in reaching all eligible organizations for future competitions?
- How effective is TIP at communicating program news and reaching new potential proposers?
- What portion of the mailing list is likely to propose research, and what are the major reasons an organization does not propose research to the program?

Preliminary Results

Westat fielded the survey for TIP in the fall of 2009. Conducting the survey 12 to 18 months after the competition allows for analysis of what research and results, if any, have occurred for organizations applied for but did not receive TIP support. This "control group" allows TIP to better analyze the efficacy of its funding on R&D outcomes.

TIP contacted 2,732 individuals from the TIP mailing list. These individuals were contacted by e-mail initially and asked to go to the survey website. Westat made a follow-up phone call to individuals who did not respond to the original e-mail encouraging participation in the survey.

There were 900 respondents to the survey. Some respondents did not answer all the questions. The final data were received at TIP on December 30, 2009. The preliminary analysis of these responses begins to answer the following questions:

How effective is TIP outreach in reaching all eligible organizations for future competitions?

Figure 7 provides a breakdown of the types of organizations represented by the 900 respondents, illustrating the diversity of TIP's audience.

In later questions asking about the technologies relevant to critical national needs, TIP asked which areas the respondents' R&D portfolio addressed. The respondents demonstrated that TIP reached a broad audience in different technical areas. Respondents could indicate multiple research areas. See Figure 8 for the breakdown by research areas.

How effective is TIP at communicating program news and reaching new potential proposers?

About 64 percent of respondents are aware of TIP's white paper process, and about half of those who are aware of the process have submitted white papers.

TIP has begun to reach audiences beyond those who were included in the former Advanced Technology Program (ATP) mailing list. The preliminary customer survey data show the following:

Photo Credit: ©iStockphoto/Fertnig Photography

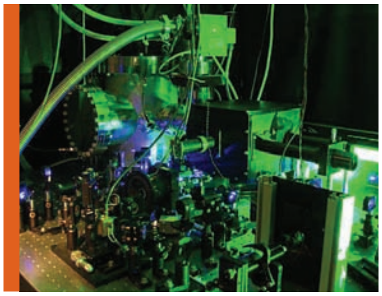
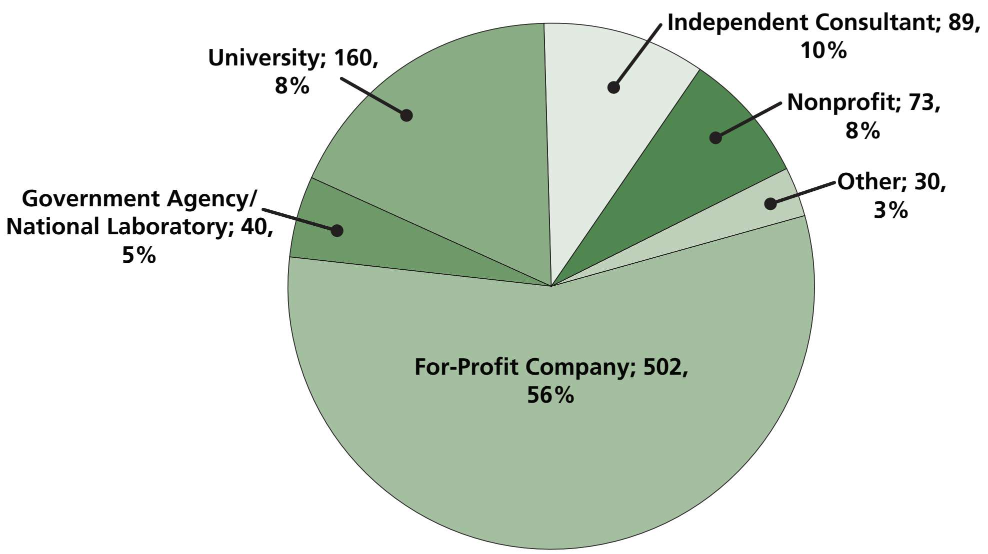


Photo Credit: NIST/O.L.A. Monti, T.A. Baker, D.J. Nesbitt/JILA

Photo Credit: ©iStockphoto/Aggressive Entertainment

Figure 7. Respondents to the TIP Customer Survey by Organization Type



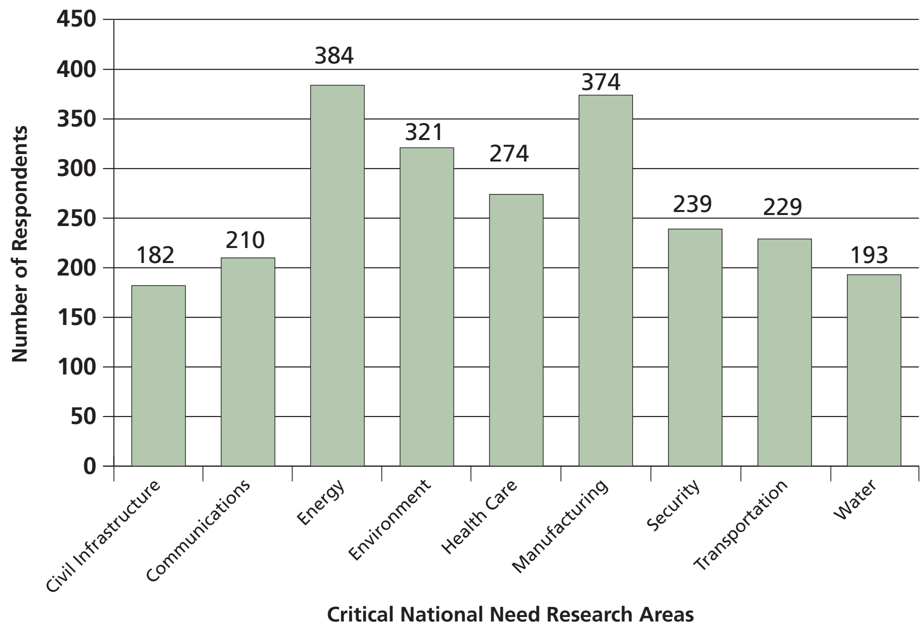
- 65 percent of the respondents' organizations were on the ATP mailing list
- 11 percent of the respondents' organizations were not on the ATP mailing list
- 24 percent of respondents did not know whether their organization was on the ATP mailing list

What portion of the mailing list is likely to propose research, and what are the major reasons an organization does not propose research to the program?

Of the 900 respondents, about 800 had not submitted a proposal. The respondents were asked why they had not submitted a proposal and could check multiple reasons for not submitting a proposal. The most commonly cited reasons were as follows:

- **Required cost share was too high**
  386 (48 percent)
- **2008 topics did not match organization's interests or capabilities**
  321 (40 percent)
- **Low probability of winning**
  338 (42 percent)
- **Too much work to write a proposal**
  293 (37 percent)
- **Could not get research partners in time**
  248 (31 percent)
- **Could not develop proposal in time**
  181 (23 percent)
- **Organization does not do high-risk research**
  134 (17 percent)
- **Organization not eligible under** TIP
  115 (14 percent)

Figure 8. Respondents' R&D Portfolio Areas Relevant to Critical National Needs



As might be expected, cost-shared funding, topic areas, and perceived chances of winning played key roles in determining whether a respondent decided to submit a proposal.

Cost-shared funding, topic areas, and perceived chances of winning played key roles in determining whether a respondent decided to submit a proposal.

The analysis of the data from this study is preliminary at this time.

APPENDIX A ▶ Abstracts for 2009 TIP Awards

Manufacturing Projects

Production of Low-Cost, High-Quality Metallic and Semiconducting Single-Walled Carbon Nanotube Inks

Brewer Science, Inc.
(Rolla, MO; Joint Venture Lead)

Project Duration: 3 years
Projected TIP Contribution: $6,527 K
Total Project Cost (est.): $13,910 K

Brewer Science, in conjunction with SouthWest NanoTechnologies (SWeNT) (Norman, OK), is developing a set of technologies for the cost-effective, commercial production of high-purity, high-quality single-walled carbon nanotube ink solutions. After many years of research, carbon nanotubes have emerged as one of the most promising classes of "nanomaterials"—advanced materials that exhibit unique, functional properties in nanoscale structures. A major obstacle to commercializing products from these carbon nanotube materials is the lack of affordable high-purity, high-quality single-walled carbon nanotubes. Conventional methods produce carbon nanotubes that are not readily suitable for enabling high-performance applications. Brewer Science has developed processes to purify, separate, disperse, and manufacture metallic and semiconducting carbon nanotube ink solutions. Applying these processes to the raw carbon nanotubes manufactured by SWeNT yields a new generation of commercial-scale single-walled carbon nanotube inks that can be applied with a variety of deposition techniques. These conductive and semiconducting carbon nanotube inks will enable domestic leadership in a variety of applications, including photovoltaics, supercapacitors, solid-state lighting, energy storage, printed electronics, and sensors. The demand shown for such a solution makes the work from this project valuable to the successful production, separation, purification, dispersion, and scale-up of cost-effective technologies that are required to address the needs satisfied by these high-performance carbon nanotube inks.

Functionalized Nanographene for Next-Generation Nano-Enhanced Products

Angstron Materials, LLC
(Dayton, OH)

Project Duration: 3 years
Projected TIP Contribution: $1,494 K
Total Project Cost (est.): $2,988 K

Angstron Materials, a world leader in the production of nanographene platelets, is developing a process to modify the tiny flakes of graphene by attaching tailored molecules to their surfaces to match them to specific applications, a process called chemical functionalization. Graphene, carbon in the form of a flat sheet of hexagonally arranged atoms, has been shown to have striking material properties; among other things, it has the highest intrinsic strength and the highest thermal conductivity of all existing materials, as well as exceptional in-plane electrical conductivity and electron mobility that is 100 times faster than silicon. In addition, graphene is far cheaper to make than nanotubes. Nanographene platelets are being investigated as critical ingredients in several energy storage and conversion products, such as high-capacity lithium-ion batteries, high-capacity supercapacitors, fuel cells, wind turbine blades, lubricants, and solar cells. The ability to modify graphene platelets in a continuous, cost-effective manner is the next step toward broad implementation of this high-performing material in next-generation nano-enhanced products. Angstron will develop methods for mass-producing functionalized nanographene platelets through the development of scalable surface treatment procedures for pristine graphene and graphene oxide platelets. Angstron will develop an in-depth understanding of the relationships among processing, shape, and structure changes and performance in nanographene platelets and devices or composites that include them for both functional and load-bearing applications. Angstron's work will support the use of nanographene platelets in thin films or coatings (for electromagnetic interface shielding, electrostatic spray painting, and conductive adhesive), composites, and thermal management applications.

Transformational Casting Technology for Fabrication of Ultra-High-Performance Lightweight Aluminum and Magnesium Nanocomposites

University of Wisconsin–Madison (Madison, WI)

Project Duration: 5 years
Projected TIP Contribution: $4,863 K
Total Project Cost (est.): $10,092 K

This joint-venture team led by the University of Wisconsin–Madison includes Eck Industries, Inc. (Manitowoc, WI), Nanostructured & Amorphous Materials, Inc. (Houston, TX), the Oshkosh Corporation (Oshkosh, WI), and Wisconsin Alumni Research Foundation (Madison, WI). This joint venture is attempting to develop a commercial-scale method for thoroughly mixing and dispersing nanoparticles in molten metals to enable the manufacture of large and complex metal castings with greatly enhanced performance characteristics. The properties of aluminum and magnesium alloys can be enhanced considerably if nanoparticles, usually ceramics, are used as a reinforcement to form metal matrix nanocomposites (MMNCs). To date, the use of these nanocomposites has been limited to relatively small and uncomplicated shapes because of the difficulty of evenly dispersing the nanoparticles. To meet this need, the joint venture plans to scale up an experimental technique developed at the University of Wisconsin–Madison that uses high-intensity ultrasonic waves to disperse the nanoparticles through molten metal. If successful, however, commercial scale production of these metal nanocomposites will enable transformative changes in multiple industries, directly addressing the critical national needs of reducing oil dependency, lowering greenhouse gas emission, and maintaining U.S. leadership in manufacturing.

High-Speed, Continuous Manufacturing of Nano-Doped Magnesium Diboride Superconductors for Next-Generation MRI Systems

Hyper Tech Research, Inc. (Columbus, OH)

Project Duration: 3 years
Projected TIP Contribution: $3,000 K
Total Project Cost (est.): $6,050 K

Hyper Tech Research, Inc., is developing an industrial-scale process for the continuous manufacture of superconducting wires using a relatively new high-temperature superconductor, magnesium diboride. Unlike ordinary metal wire, present-day superconducting wires currently used in magnetic resonance imaging (MRI) are manufactured using a relatively expensive and labor-intensive batch process, which limits the maximum possible length of a single wire, thus the desire for a continuous manufacturing process to reduce manufacturing costs, and increase piece lengths. Because magnesium diboride superconductor starts out as a powder mixture, the powder can be placed in a continuous formed and filled tube with an outer metallic sheath, such as iron or niobium, to distribute the powder along the wire. Then several monofilament wires will be restacked continuously into another copper or copper-nickel-formed tube to manufacture a multifilament superconductor wire. Hyper Tech Research, which has been working on improving the performance of magnesium diboride superconductors using nanopowder additives, is scaling up an experimental Continuous Tube Forming and Filling Process (CTFF) to convert magnesium diboride wire from batch processing to high-speed, continuous manufacturing, demonstrating uniform mixing of nano-size additives and micro-size powders, continuously monitoring and dispensing the powders at high speeds, and demonstrating process modeling and adaptive control for both monofilament and multifilament wires. If successful, the project will enable relatively low-cost high-temperature superconducting wires for MRI and electric power applications. The basic technology will have application in the production of flux-cored welding wire, specialty alloys, and the small-diameter tubing market as well.

PRINT® Nanomanufacturing: Enabling Rationally Designed Nanoparticles for Next-Generation Therapeutics

Liquidia Technologies, Inc. (Durham, NC)

Project Duration: 3 years
Projected TIP Contribution: $2,971 K
Total Project Cost (est.): $5,942 K

Liquidia Technologies is developing a novel, top-down approach to nanoparticle fabrication that uniquely enables simultaneous and precise control over nanoparticle size, shape, and composition, as well as surface functionalization, to adapt the nanoparticles to specific tasks for medicine. Nanoparticle drug delivery systems have the potential for transformational results in healthcare, with the unique ability to access and target specific tissues, cell types, and biological systems. Advances in the technology can enable superior efficacy with novel therapeutics and minimize toxicity by specifically targeting certain cell types. Liquidia's Particle Replication in Non-wetting Templates (PRINT®) technology brings the precision and uniformity of the semiconductor industry together with the scale and cost structure of the films industries to create novel, complex particles with simultaneous control over structure and function. Widespread, practical use, however, will require much higher manufacturing efficiencies than currently possible. This project aims to increase the current nanoparticle manufacturing capability by 1,000-fold. To achieve this, the company is attempting to simultaneously increase the scale of the process, improve its performance, and reduce the process time. Unlike other nanoparticle manufacturing techniques, PRINT nanomanufacturing lends itself to a continuous "roll-to-roll" process of the sort used to make paper, films, and tapes. If successful, the project will enable new, continuous manufacturing capabilities to create engineered nanoparticle products in clinically relevant quantities and potentially could enable entirely new clinical products based on that capability.

Silicon Nanowire Production for Advanced Lithium-Ion Batteries

Amprius, Inc. (Menlo Park, CA)

Project Duration: 2 years
Projected TIP Contribution: $3,000 K
Total Project Cost (est.): $6,000 K

Amprius, Inc is working to develop a unique, high-throughput, continuous manufacturing process for producing a novel, nanostructured silicon-based anode material for lithium batteries. Higher energy density batteries would have a major impact on the development of electric vehicles by extending driving range and lowering costs. Amprius has demonstrated anodes made of silicon nanowires that are tolerant of strains and that can expand and contract without breaking for hundreds of cycles. A practical battery with a silicon nanowire anode could increase the energy density of today's lithium batteries by 40 percent, even at realistic levels of material utilization. Amprius currently makes silicon nanowires in a small-scale batch process using chemical vapor deposition, a process borrowed from the semiconductor industry. The company hopes for a 1,000-fold scale-up of manufacturing capability, and the current project will explore two potential paths toward a large-scale process to produce silicon nanowire anodes "by the mile." After initial feasibility studies, the most promising approach will be developed. If successful, the process will represent the first continuous "roll-to-roll" process to deposit three-dimensional silicon-based nanostructures. In addition to the manufacture of advanced batteries, this continuous throughput technology would likely benefit other industries, including solar photovoltaic, energy storage, and solid-state lighting industries.

Integrated Multiscale Modeling for Development of Machinable Advanced Alloys and Corresponding Component Machining Processes

Third Wave Systems, Inc. (Minneapolis, MN)

Project Duration: 3 years
Projected TIP Contribution: $1,564 K
Total Project Cost (est.): $3,170 K

Third Wave Systems is working to develop a complex, physics-based predictive modeling system to develop advanced alloys that would incorporate data on how best to machine the planned alloy. This would close a major gap that currently exists in the development and application of new, high-performance metal alloys. Currently, there is a disconnect between alloy developers and the manufacturing base of industries that want to machine advanced alloy components in a fast and affordable manner. Each new alloy presents a new combination of toughness, ductility, heat sensitivity, and a variety of other characteristics that need to be considered when the material is machined. This project will extend the capabilities of computational alloy design, an emerging approach to alloy development. In current computational design, structure-property models are used to predict an optimal alloy microstructure for a specific set of desired final properties, and process-structure models determine an optimal processing scheme to arrive at that microstructure. What is missing is the incorporation of machinability considerations into the process plan and physics-based models that could predict optimum machining parameters like tool speeds and feed rates based on the alloy's microstructure. The project will create a high-performance computing environment, enabling rapid turnaround for cutting tool design and toolpath development for machined advanced alloy component. If successful, it will enable U.S. manufacturers to produce highly machinable, advanced alloys through the coupling of micromechanical models with physics-based machining models. The results will be applicable not only to machining of advanced alloys, but also to general metal machining.

High-Volume Production of Nanocomposite Electrode Materials for Lithium-Ion Batteries

A123Systems, Inc. (Ann Arbor, MI)

Project Duration: 3 years
Projected TIP Contribution: $2,864 K
Total Project Cost (est.): $6,000 K

A123Systems, Inc. is developing a new nanocomposite material for lithium ion battery electrodes together with improved manufacturing process technologies to enable both significantly improved battery performance and lower manufacturing costs. With their high energy-to-weight ratios, lithium ion batteries are an important enabling technology for electric vehicles, upgrading the electric utility grid, and increasing the use of variable renewable energy sources, such as wind and solar power. A123Systems has an existing iron-phosphate nanocomposite electrode material. The current project pursues a novel second-generation nanomaterial that would replace some or all of the iron with manganese, increasing the battery's energy density and therefore reducing cost per watt-hour. This project also will develop a number of improvements to the manufacturing process used to make the nanoparticles, which should result in a threefold increase in manufacturing throughput. Because capital equipment and facilities are primary factors in the cost of electrode materials, increasing throughput offers the best leverage for cost reduction. The ultimate goal of the project is to scale up from 10 grams per lab batch to more than 10 kilograms per day production in a quasi-continuous pilot demonstration.

Building U.S. Strategic Metals Competitiveness through Integration of Advanced Sensor Technologies

wTe Corporation
(Bedford, MA; Joint Venture Lead)

Project Duration: 4 years
Projected TIP Contribution: $5,670 K
Total Project Cost (est.): $11,532 K

This joint research venture led by wTe Corporation together with National Recovery Technologies, Inc. (Staten Island, NY) and Energy Research Co. (Nashville, TN) is working to combine and scale up a suite of technologies to build an efficient, integrated recycling system for high-value alloy scrap in the aerospace industry. This project focuses on recycling two high-performance specialty alloys used by the aerospace industry, titanium-based alloys and the nickel- or cobalt-based "superalloys." These are extremely high-performance and costly alloys, but the scrap often cannot be reused in aerospace applications because it is too expensive to recycle given current practices or because it is too contaminated to recycle as the original high-grade alloy. As a result, it must be downgraded to inferior product uses and applications. The joint venture team is scaling up a group of novel optical technologies to (1) automate the sorting of scrap metal at high speeds and volumes, sorting each piece by composition, and (2) provide real-time, continuous analysis of the composition of molten metal in high-temperature alloy furnaces, which will allow furnace operators to change the melt while it is being processed. The novel technologies, based on optical and x-ray spectroscopy, would both significantly refine the waste metal stream and enable alloy producers to accommodate changing scrap metal input and furnace conditions to produce precise alloy chemistries. Such tight control of alloy chemistry not only would enable the production of better alloys but also would reduce production time and eliminate "bad heats," saving energy and raw materials. If successful, the project would lessen U.S. dependence on supplies of strategic virgin metals recovered at primary refineries from ore (most of which are purchased abroad), and enable substantial energy savings from the use of scrap rather than ore and virgin metals. Emissions also would be greatly reduced because secondary smelting consumes much less energy than primary production followed by remelting.

Homogeneous Three-Dimensional Pultruded Processing of PEEK, PEI, and PPS High-Temperature Thermoplastic Composite Profiles

Ebert Composites Corporation
(Chula Vista, CA)

Project Duration: 2 years
Projected TIP Contribution: $1,866 K
Total Project Cost (est.): $4,018 K

Ebert Composites Corporation is developing a novel manufacturing process to produce large, three-dimensional, fiber-composite components from a variety of high-temperature thermoplastics. Thermoplastics are strong, flexible materials that turn liquid when heated above a critical temperature. They are manufactured as a thin tape of the composite material, such as carbon fibers, impregnated with the thermoplastic. Manufacturers buy this "prepreg" tape and then cut, braid, and form it into more complex shapes that are heated and formed in a mold to produce the finished part. In addition to requiring several steps and much labor, the process limits the size and complexity of the shapes that can be made. Ebert has pioneered the production of continuously formed, three-dimensional shapes from thermoset composites using the "pultrusion" process. In this project, the company is developing a radically different manufacturing process to achieve the same thing with high-temperature thermoplastics. The process will produce components that can be larger than any existing thermoplastic mold and that are equally strong in all three dimensions (a problem with today's prepreg-based components). If successful, the project could revolutionize the composites industry, enabling larger and stronger thermoplastic composite components at a quarter the cost of the current state of the art.

High-Risk, Low-Cost Carbon Nanofiber Manufacturing Process Scale-Up

eSpin Technologies, Inc. (Chattanooga, TN)

Project Duration: 3 years
Projected TIP Contribution: $3,000 K
Total Project Cost (est.): $6,006 K

eSpin Technologies, Inc. is conducting research to scale up a manufacturing process to produce commercial quantities of self-supporting, nonwoven fabrics of both natural and activated carbon nanofibers. These fabrics have a wide range of potential applications. The current focus is on the development of low-pressure-drop, high-performance molecular air filter media. eSpin already manufactures nonwoven nanofiber materials with a polymer nanofiber fabric used for particulate air filters. Carbon nanofibers have high ratios of surface area to mass, which produces extremely lightweight and high-performance materials. Manufacturing these innovative carbon nanofiber products on a commercial scale requires solving several major technical challenges. The fabrics initially are produced by fabricating a nonwoven nanofiber web from an organic polymer. The web is then carbonized by a high-temperature thermal process. Nanofiber materials are extremely fragile and customarily are made on a substrate that provides support. A substrate, however, cannot be used for the thermal processing stage. Therefore a major challenge will be to produce a free-standing self-supporting nanofiber web. Additional engineering challenges include managing heat flow, removing off-gases and residual solvent, transporting the web, and controlling the carbon structure within the nanofibers. eSpin estimates that molecular air filters—their target application—if widely utilized could save the Nation trillions of joules of energy annually. In addition, the fundamental technology for producing free-standing nonwoven carbon nanofiber materials would have a wide variety of applications in carbon-fiber composite materials because of their high strength-to-weight ratio and their relatively low cost, whereas activated carbon nanofibers are expected to have applications in energy storage devices among many other uses.

Development and Scale-Up of Nanocomposites with Sub-10 Nanometer Particles

Pixelligent Technologies, LLC (College Park, MD; Joint Venture Lead)

Project Duration: 3 years
Projected TIP contribution: $4,089 K
Total Project Cost (est.): $8,178 K

A research joint venture led by Pixelligent Technologies, LLC, partnered with Brewer Science, Inc. (Rolla, MO), is developing new processes and technologies to scale up the production of high-quality nanocomposites—nanocrystals dispersed in polymers—to create materials with enhanced performance and new functionality that cannot be provided by polymers or traditional composites. Their initial target applications are new materials for the optoelectronics and semiconductor industries. Adding tailored nanocrystals to polymers can result in materials with a broad range of enhanced properties, depending on the combination. Polymer nanocomposites can be designed that are tougher, stronger, stiffer, more heat resistant, better conducting, more fire and chemical resistant, and more biocompatible. Working with Brewer Science, Pixelligent aims to scale their production of high-quality metal oxide nanoparticles from grams to kilograms while maintaining their ability to control the size and shape of the particles within narrow ranges, and prevent them from clumping together, a common problem with nanoparticles. Their two target applications are novel polymer nanocomposites, one with a high index of light refraction and other necessary properties for use in high-efficiency light-emitting diodes (LEDs), and the other a novel microlithographic layer for semiconductor processing that can be used in thinner coatings to support next-generation levels of microcircuit lithography. If successful, the basic nanocomposite processing advances developed in this project should extend to a wide range of nanocomposite materials.

Civil Infrastructure Projects

Civil Infrastructure Inspection and Monitoring Using Unmanned Air Vehicles

The Droid Works, Inc. (Framingham, MA)

Project Duration: 3 years
Projected TIP Contribution: $2,453 K
Total Project Cost (est.): $4,996 K

The Droid Works (currently in the process of changing its name to CyPhy Works), together with the Georgia Institute of Technology Research Corporation, is attempting to develop a novel and potentially revolutionary inspection system based on small, unmanned, hovering robots fitted with video cameras and other sensors. The proposed Unmanned Air Vehicle (UAV) would slowly move along the sides or undersides of bridges and similar structures while relaying close-up, high-fidelity images and other data to engineers for "Robotic Assisted Inspection." Because the robots would not need to shut down bridge lanes or to rig safety harnesses, they would greatly increase both the speed and safety of bridge and dam inspections. For particularly critical or at-risk structures, inspectors could use "Autonomous Robotic Monitoring"—one or more dedicated inspection robots that would be stationed at the structure and make periodic flights to detect potentially dangerous changes. Both approaches will require major advances in the current state-of-the-art small UAVs to allow them to fly and hover safely in potentially gusty winds for long periods with precise positioning. Current UAV technology, for example, uses Global Positioning Satellite (GPS) signals to maintain position, but the technique cannot maintain position within extreme proximity of a large structure. Droid Works envisions an optics-based close-in navigation system that allows the robot to maintain a position and navigate by observing visual cues such as corners or edges of the structure. If successful, the project will produce an advanced class of UAVs that would enable entirely novel, efficient, and relatively low-cost techniques for monitoring the health of the Nation's existing civil infrastructure. The autonomous monitoring capability is critically needed for bridges and dams that are rated as substandard to warn of impending catastrophic failure.

Automated Nondestructive Evaluation and Rehabilitation System (ANDERS) for Bridge Decks

Rutgers, The State University of New Jersey (Piscataway, NJ; Joint Venture Lead)

Project Duration: 5 years
Projected TIP Contribution: $8,810 K
Total Project Cost (est.): $17,923 K

This joint venture led by Rutgers' Center for Advanced Infrastructure and Transportation (CAIT) includes Drexel University (Philadelphia, PA), PD-LD, Inc. (Pennington, NJ), Mala GeoSciences USA, Inc. (Charleston, SC), and Pennoni Associates, Inc. (Philadelphia, PA). The joint venture is developing a suite of technologies that together will provide a comprehensive solution to bridge-deck maintenance—from monitoring and assessment to remediation and overall bridge inspection. The goal is to develop the Automated Nondestructive Evaluation and Rehabilitation System (ANDERS) for bridge decks, which will use a combination of human-operated and robotic vehicles that allow rapid, comprehensive application across a large number of bridge types and potentially other infrastructure as well. ANDERS will be composed of four systems that merge novel imaging and nondestructive evaluation techniques with innovative intervention approaches to arrest deterioration processes in bridges. To assess deck conditions, ANDERS will use two complementary nondestructive evaluation systems. A Multimodal Nondestructive Evaluation System will combine ground-penetrating radar, impact echo, and ultrasonic probes to identify and characterize localized deterioration. In tandem, a Global Structural Assessment System will use modal analysis (i.e., observation of how a structure vibrates in response to a mechanical stimulus) to assess global structural characteristics, identify any appreciable effects of deterioration on the bridge structure as a whole, and shed light on how local deterioration effects global performance of the structure. Output from these two methods will be merged using an automated analysis system. Based on the outcome of these assessments, a Nondestructive Rehabilitation System will use robotic repair equipment to deposit specially formulated repair materials to fill and bond hairline crevasses and repair delamination. ANDERS will provide much more detailed and comprehensive detection of early onset deterioration and result in both time and cost-savings compared with traditional approaches.

Distributed Fiber-Optic Sensing Technology for Civil Infrastructure Management

Optellios, Inc.
(Newtown, PA)

Project Duration: 3 years
Projected TIP Contribution: $1,930 K
Total Project Cost (est.): $3,917 K

Optellios, Inc is developing a novel and potentially widely deployable technology for monitoring the status and integrity of water pipelines and other similar structures using fiber-optic cables. Instead of using a large number of individual sensors that would be required to monitor a lengthy stretch of pipelines, the optical fiber would act as a continuous sensor providing real-time data about the location and nature of acoustical and temperature changes in the sensor's surroundings over distances of tens of miles. At present, no single sensor system is capable of providing such detailed real-time monitoring capability. Monitoring for thermal and acoustic anomalies along water pipelines will help detect water loss caused by leaks, while simultaneously detecting structural changes associated with aging infrastructure by monitoring acoustic emissions. The key innovation, and most difficult challenge, is the use of a complex analysis of how specially tailored light signals, sent down the fiber, are scattered and reflected back from various points along the path. The specific character of the returned light—changing with time depending on how far it traveled—will reflect local conditions of the optical fiber at each point along its run, including both transient effects, such as vibrations, and more static conditions, such as temperature and strain. Although the current research targets the in-ground water infrastructure, including water mains and wastewater systems, potential applications exist across many other critical infrastructure sectors. If such a monitoring system were successfully developed, it is expected to become a valuable tool for infrastructure management because it could assist the operators in prioritizing maintenance schedules and prevent costly repairs and accidents.

Robotic Rehabilitation of Aging Water Pipelines

Fibrwrap Construction, Inc.
(Ontario, CA; Joint Venture Lead)

Project Duration: 5 years
Projected TIP Contribution: $8,462 K
Total Project Cost (est.): $17,582 K

This joint research venture led by Fibrwrap Construction and including Fyfe Company (San Diego, CA) and the University of California, Irvine is working to design and build a prototype robot to repair and retrofit aging water mains by applying a tough, carbon-fiber reinforcement material to the insides of pipes without the need for costly excavation or replacement. The United States is served by a sophisticated water infrastructure consisting of 2 million miles of water transmission pipelines, most of which, are aging and in some cases failing prematurely. This project aims to construct a prototype robot able to apply high-strength, high-stiffness, low-cost carbon fiber internally to strengthen underground pipelines and prevent them from bursting and collapsing. The task of evenly and thoroughly applying a carbon fiber coating to the insides of old pipes with unpredictable flaws, imperfect shapes, and uneven surfaces is a significant technical challenge. The proposed robot would employ advanced sensor systems to monitor the contact pressure against the pipe wall and synchronize the application process with the motion of the robot. Able to lay carbon fiber eleven times faster than human crews, the pipe-repair robot will be able to adapt to variable-sized pipes and conditions. In addition to formal members of the joint venture, the project is supported by the East Bay Municipal Utility District; the San Diego County Water Authority; the District of Columbia Water and Sewer Authority; and construction engineers Simpson, Gumpertz & Heger. If successful, the project will develop and commercialize the robotic system, which potentially could give the Nation a lead in a growing world market for water infrastructure technology.

A Rapid Underground Pipe Rehabilitation Technology

LMK Enterprises, Inc.
(Ottawa, IL)

Project Duration: 2 years
Projected TIP Contribution: $1,701 K
Total Project Cost (est.): $3,411 K

LMK Enterprises is developing a novel technology for repairing and rehabilitating underground pipes from the inside, without the need to dig trenches to expose the damaged pipe. The project employs a novel dynamic resin-injection, molded-in-place pipe process. A quick-curing composite resin that could include recently developed nanomaterials for additional strength is mixed in place by an extruding device that applies the mixture between an inflatable bladder and pipe wall, providing a smooth and even surface. The proposed LMK technology offers several advantages over current technologies such as increased productivity by significantly reducing installation time; reduced cost by eliminating the need for a custom-tailored resin-impregnated liner tube; improved mechanical properties by employing nanomaterials; and enhanced performance by yielding smooth and uniform wall thickness. The proposed technology has a broad application potential, because it can be used to rehabilitate all types of pipes, including potable water, sewer, gas, oil, steam, and compressed air, and these markets offer a significant opportunity.

Development of a Multiscale Monitoring and Health Assessment Framework for Effective Management of Levees and Flood-Control Infrastructure Systems

Rensselaer Polytechnic Institute (Troy, NY; Joint Venture Lead)

Project Duration: 4 years
Projected TIP Contribution: $3,462 K
Total Project Cost (est.): $6,928 K

This joint venture led by Rensselaer Polytechnic Institute partnering with Geocomp Corporation (Boxborough, MA) is developing a new health assessment framework with the potential to revolutionize our ability to monitor, manage, and ensure the safety of levees and other systems of a flood-control infrastructure. The integrity and reliability of levees, earthen dams, and flood-control infrastructure are essential components of homeland safety. Levees, earthen dams, and similar structures are difficult structures to assess not only because of their sheer size, but also because they are constructed of complex geological materials, somewhat random in composition, with intricate degradation mechanisms. The planned framework provides a comprehensive multiscale monitoring and analysis for real-time health assessment of this infrastructure. This framework relies on long-term continuous monitoring techniques that are minimally intrusive and inexpensive, and include satellite-based interferometric synthetic aperture radar (InSAR) measurements and a new high-resolution shape-acceleration-pore pressure (SAPP) array able to measure soil displacements and movements over local areas for tens of meters. The planned system would provide for the first time a long-term, continuous assessment of the health of levee systems on both local and global scales, allowing Federal, state, and local governments to prioritize repairs and rehabilitation efforts, and assess the effectiveness of those efforts before a serious failure. The new health assessment framework will be implemented and benchmarked through an ambitious field test in the New Orleans area. This test will be conducted by the U.S. Army Corps of Engineers and fully funded by the Department of Homeland Security. If successful, the project innovations will transform the field of geohazard mitigation to enable more global and holistic approaches, and thereby enable a better management and more reliable flood-control infrastructure.

Development of High-Toughness, Low-Viscosity Resin for Reinforcing Pothole Patching Materials

University of California, Los Angeles (Los Angeles, CA; Joint Venture Lead)

Project Duration: 3 years
Projected TIP Contribution: $1,499 K
Total Project Cost (est.): $3,051 K

A joint research team led by the University of California at Los Angeles in partnership with Materia, Inc. (Pasadena, CA), together with the Department of General Services of the City of Los Angeles as a subcontractor, is developing an innovative pothole repair technology for asphalt pavement in both warm and cold weather. Thus far, most technical approaches to pothole repair have focused on improving the processing and deployment of the asphalt patches. This project takes a radically different approach, infiltrating the compacted asphalt-aggregate mixture with an ultra-high toughness, nano-molecular resin. After the resin is infiltrated, cured, and hardened, it will form a continuous network of mechanical "cages" that will provide mechanical locking of the aggregates in the asphalt mixture, serve as a load-bearing component under repeated traffic stresses, provide compressive shear-load strength, anchor patches to the original pavement walls and sub-bases, prevent water infusion, and serve as barrier for the initiation and propagation of alligator cracks. The Department of Public Works of the City of Los Angeles and the California Department of Transportation will support the deployment of the new repair materials and technology to street test sites. If the project is successful, it will fundamentally revolutionize the asphalt pavement preservation and pothole patching repair methodology and dramatically enhance the strength, durability, and service life of the asphalt pavement and pothole repair patching practices.

Advanced Coating Technology for Infrastructure

MesoCoat, Inc. (Euclid, OH; Joint Venture Lead)

Project Duration: 3 years
Projected TIP Contribution: $1,792 K
Total Project Cost (est.): $3,956 K

This joint research venture led by MesoCoat, together with The Edison Materials Technology Center (Dayton, OH) and Polythermics, LLC (Kirkland, WA), is developing a novel coating technology to change the way large steel and steel alloy structures are protected from corrosion. Steel structures, including bridges, pipelines, and support structures, are subject to corrosion and attack from the atmosphere, acid rain, salt, and chloride ions, among others. This project is developing large area nanocomposite, corrosion-resistant coating materials and a high-rate, low-cost application technology. Novel, high-intensity infrared light sources will be used to fuse nanocomposite metal-ceramic and polymer coatings onto steel surfaces of large structures, replacing electroplating, chromate primers, hot-dip galvanizing, and fusion-bonded epoxy coatings. If successful, the application system, which relies on a scalable high-intensity white light optical source, will be able to rapidly heat a surface to remove old paint or polymer coatings with minimal hazardous waste or volatile organic emissions. The same application system can be used to remove damaged concrete as well as to repair and reinforce metallic pipe at rates that are ten to a hundred times that of weld cladding. This project's technology would provide a complete, portable system to strip coatings and to apply high-performance metal primers and zero volatile organic compound (VOC) polymer topcoats with improved performance at lower cost.

APPENDIX B ▶
TIP Award Criteria and Competition Process

The **TIP** competition process is focused on identifying proposals that best meet the **TIP** award criteria and that address the societal challenge defined in the solicitation. The goal of the process is to collect 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 define project characteristics that make the projects competitive. The full **TIP** award criteria as defined in the **TIP** Rule 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 has scientific and technical merit and may result in intellectual property vesting in a United States entity that can commercialize the technology in a timely manner.

(e) The proposal establishes that the research has strong potential for advancing the state-of-the-art and contributing significantly to the United States science and technology knowledge base.

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

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