

# **PARTNERSHIP FOR THE ADVANCEMENT OF INFRASTRUCTURE AND ITS RENEWAL THROUGH INNOVATIVE TECHNOLOGIES (PAIR) WHITE PAPER**

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**NIST**

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**Partnership for the Advancement of Infrastructure and Its Renewal  
Through Innovative Technologies (PAIR)  
White Paper**

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*The scope of PAIR includes the nurture and support of a great variety of innovative technologies, products, practices, and processes. In this context, these terms are often used somewhat interchangeably.*

## EXECUTIVE SUMMARY

Each person and every business depends on the nation's infrastructure, but innovation in infrastructure is not always keeping pace with business innovation and market demands and human needs. Modernizing and maintaining our infrastructure—by some estimates likely to require a more than \$1.3 trillion investment—represent both a pressing national need and a tremendous market opportunity for innovative products and practices. Unless private sector businesses and government join in a collaborative effort to accelerate the pace of infrastructure innovation, America's 21<sup>st</sup> century businesses will be shackled by the high costs of an ineffective, decayed, inadequate, and obsolete infrastructure. Further, we will miss global market opportunities for developing new ideas, science, and technology to improve infrastructure. Yet we lack both broad public appreciation of the problems and opportunities, and solid constituency for infrastructure innovation that spans infrastructure's functional range: telecommunications, utilities, water supply and sewerage, transportation, and public facilities.

Leaders from industry, non-government organizations, academia, and the public sector have come together to support and build this constituency. This initiative—which we have termed the **Partnership for the Advancement of Infrastructure and its Renewal (PAIR)**—seeks to accelerate product and process innovation in the construction, maintenance and repair of our nation's infrastructure. PAIR's basic premise is that **all of us, in both the private and public sectors, are users of the infrastructure and therefore stakeholders in its advancement and renewal.** Together we can motivate and shape collective action.

PAIR is conceived as an umbrella organization of existing and future government, private sector, and academic programs to develop innovative products and practices. The Partnership's scope, our national infrastructure, encompasses transport, water, sewerage, waste management, energy, and communications systems. Industry and government leaders in all of these areas are participating in PAIR as colleagues in a unique partnership. This paper presents the evolving vision, objectives, participants, and potentially valuable initiatives and resources these initiatives may entail.

### PAIR's Objectives

**PAIR was conceived as a national mouthpiece and rallying point to accelerate the construction, renewal, and advancement of our nation's infrastructure through innovation in engineered systems, technologies, products, and processes.** Much of the Partnership's effort will address non-technical barriers that slow the pace of innovation and discourage industry from commercializing promising technologies. PAIR is pursuing four inter-related objectives:

- To nurture a national constituency committed to the development and use of innovative products and processes for infrastructure and its renewal
- To create joint private and public sector R&D initiatives to aggressively develop and commercialize these new products and processes
- To identify and reduce the obstacles impeding rapid commercialization of innovative technologies, such as public acceptance of projects and technologies, procurement policies, liability concerns, workforce education and skills, and others

- To recognize and showcase innovative technologies that will address critical infrastructure needs

### **PAIR's Strategy**

PAIR recognizes that **many of the programs necessary for a broad-based constituency supporting infrastructure revitalization are already in place. The Partnership's strategy is to build on these programs** and create a climate that fosters private- and public-sector collaboration and effectively leverages limited national resources with a real sense of urgency and renewed vigor. PAIR will do this in two key ways:

- Providing its participants a “bully pulpit” for drawing attention to the nation's infrastructure needs and opportunities and disseminating information about ongoing and planned research and deployment programs. The Partnership will work to expand these programs' effectiveness, encouraging greater collaboration and leveraging of funds between and among public and private sector institutions and ultimately spurring allocations of additional funds for products and processes for innovative infrastructure.
- Helping to coordinate and facilitate the development of new programs focused on infrastructure R&D, demonstration, testing, evaluation, and technology transfer. While PAIR will not assume management responsibility for each of these programs, the Partnership will be a vehicle for their planning and coordination.

### **PAIR's Results**

From a worldwide perspective, the economic benefits of innovative products and processes for higher quality and more economical infrastructure will be trillions of dollars over the next 10 years. We anticipate ultimately being able to measure PAIR's success in terms of new commercially valuable products and processes in use, and broad public benefits stemming from better and more economical infrastructure.

The more immediate measures of PAIR's success, however, will be threefold:

- Increased understanding by business leaders, elected officials, and the public at large of how infrastructure innovation contributes to economic competitiveness, national security, and environmental stewardship
- New initiatives bringing together private- and public-sector participation to achieve specific infrastructure innovations
- Greater efficiency in the use of local, state, and federal government resources devoted to improving and maintaining the infrastructure

### **Building PAIR**

The Partnership is drawing together leaders from business and industry, government at all levels, and non-governmental organizations (e.g., public interest, trade, and professional associations), and academia. PAIR's private-sector participants to date have included representatives from banking, insurance, manufacturing, communications, transportation, and other industries that supply, use, and depend on infrastructure, as well from companies specializing in infrastructure

design, construction, and management. Government participation has come from federal, state, and local executive-branch organizations responsible for national policy as well as the development and management of our civil and military infrastructure. The list of participants is growing, as is the Partnership's commitment to action.

We seek the broadest possible involvement in PAIR's initiative. There are **three compelling reasons that working together in the Partnership will benefit participants and the nation:**

- PAIR will provide a forum for participants to **exchange views and deal effectively with key economic, technical, and political matters encouraging or impeding the successful commercialization of promising new products and processes.**
- PAIR will provide opportunities for industry leaders, public officials, academic researchers, and public interest groups to **form new collaborations for breakthroughs in infrastructure innovation.**
- PAIR will expose participants to new ideas and developments in fields outside each participant's primary area of business, thereby opening **market opportunities for new products and processes.**

### **The First Steps**

An early element of PAIR's establishment is **workshops bringing together knowledgeable, creative, experienced individuals representing the diverse business and public-sector perspectives on infrastructure advancement and renewal.** The initial workshop on April 7, 1998 focussed on innovation for transportation infrastructure. This second workshop on June 30, 1998 addressed innovation in all other areas except public buildings. These workshops are the vehicles for sharpening PAIR's strategy, setting an initial course of action, and building coalition and consensus. The future direction and pace of PAIR's activities will depend on funding and other commitments the Partnership can secure.

Based on PAIR's activities to date, we are proceeding to

- Develop an Internet presence for the Partnership
- Publish this PAIR white paper, incorporating workshop results
- Develop a fact sheet or brochure for widespread distribution
- Survey private and public sector R&D partnering and funding options
- Survey additional means for developing broad-based support for PAIR
- Focus on public- and private-sector procurement practices that impede rapid commercialization of new infrastructure products and processes

### **The Future**

The PAIR initiative will have three broad phases: near-term (1998-2002), mid-term (2003-2008), and long-term (beyond 2008), to accommodate changing priorities and foster realistic expectations. PAIR's participants to date have recommended a number of key areas for near-term action:

- Recruiting and involving a broad coalition of other organizations

- Developing a clear message to build public understanding of needs and benefits for improved infrastructure and support for infrastructure advancement
- Facilitating R&D agenda and priority development
- Pre-qualifying and pre-approving new products and processes to reduce liability
- Developing appropriate measures of infrastructure performance
- Benchmarking the state of foreign and domestic technology
- Addressing key non-technical obstacles to innovation, e.g., procurement practices, litigation risks, entrepreneurs' incentives, funding for research and demonstrations
- Promoting case studies and impact assessments
- Stimulating showcase projects for innovations

We envision that PAIR will grow as a loosely coordinated partnership of industry and government rather than a pooling of resources under one management entity. A PAIR Executive Committee comprised of private and public sector leaders will oversee PAIR. Federal participants will be provided by the Subcommittee on Construction and Building of the National Science and Technology Council (NSTC). Academic participants will be guided through such authoritative institutions as the National Science Foundation's Institute for Civil Infrastructure Systems. The Civil Engineering Research Foundation (CERF), the non-profit research affiliate of the American Society of Civil Engineers (ASCE), serves as Secretariat to the PAIR Executive Committee.

## THE PARTNERSHIP VISION

The Partnership for the Advancement of Infrastructure and its Renewal (PAIR) is conceived as an umbrella under which existing and future government, private sector, and academic programs will be jointly guided to develop the innovative products and practices needed to revitalize and advance the nation's physical infrastructure. Our national "infrastructure" comprises the transport, water, sewerage, waste management, electrical power, gas and liquid fuels, and communications systems, and everyone has a stake in its performance. While innovation abounds in many sectors of the nation's economy, in infrastructure, new technologies are not keeping pace with the demands of business markets and public priorities.

Every business depends on the nation's infrastructure. Infrastructure influences fundamentally a firm's access to markets, costs of doing business, and productivity of its workforce. Unless we can accelerate the pace of infrastructure innovation, America's 21<sup>st</sup> century businesses will be shackled by the high costs of an ineffective, decayed, inadequate, and obsolete infrastructure. Further, we will miss global market opportunities for developing new ideas, science, and technology to improve infrastructure.

The public depends on infrastructure as well. Infrastructure fundamentally influences our access to jobs and recreation, our personal health and safety, and how we function as a society. Unless we can accelerate the pace of infrastructure innovation, America's 21<sup>st</sup> century communities will suffer increasing congested systems, unreliable services, escalating costs, and deteriorating physical environment.

Many experts contend that today's infrastructure is in dire need of revitalization. The American Society of Civil Engineers estimates that the need for investment to repair and renew what we now have will be \$1.3 trillion for United States as a whole. Others point to the rapid ongoing and anticipated progress in the science, technology, and organizational structures that could be applied to enhance infrastructure's performance in the future. They see in infrastructure renewal new markets for innovative products and practices, if only innovations could be achieved.

Yet we find there are substantial obstacles to infrastructure advancement and renewal. The public at large and its leaders often lack appreciation of the needs and opportunities inherent in maintaining an effective infrastructure, and there is no major, visible constituency for innovation. The products, practices, and technologies for infrastructure renewal are diverse, disjointed, and distributed among many private and public entities. These entities represent all sectors of the economy, including telecommunications, utilities, water supply and sewerage, transportation, and public facilities. Unless businesses and government join in a collaborative effort to accelerate the pace of infrastructure innovation, we are unlikely to sustain a commitment to encouraging and nurturing high quality and economical infrastructure systems, components and materials.

PAIR will work to build collaborative partnerships that share a strong and common commitment to infrastructure advancement and renewal. The Partnership will address the full spectrum of needed innovations. Novel engineered products and systems for meeting society's infrastructure needs will emerge from the PAIR enterprise. Such innovations will include high-performance construction materials that cut costs and enhance safety and aesthetic possibilities. "Intelligent" operating systems that improve service without new construction, remote sensing and rapid-response to reduce the congestion, economic losses and environmental damages caused by fluctuations in demand, storms, collisions, and other random or unforeseen events. These results will be embodied in tangible new technologies, but their impact will be felt in a more productive economy and an improved living environment for everyone.

The cornerstones of PAIR's establishment are the workshops that bring together knowledgeable, creative, experienced individuals representing the diverse business and public-sector perspectives on infrastructure advancement and renewal. An initial workshop focusing particularly on transportation infrastructure (PAIR-T) was held April 7, 1998; the second workshop on June 30, 1998 was focused on telecommunications, utility, and water supply and sewerage infrastructure. A third workshop may be devoted to considering issues particularly relevant to public facilities such as schools, health-care services, and government administration. Each workshop is a means for sharpening PAIR's strategy, setting its initial course of action, and building the coalition and consensus that PAIR embodies. The future direction and pace of PAIR's activities will depend on what funding and other commitments the Partnership can secure.

### **PRIORITY ISSUES FOR PAIR**

PAIR will grapple with a range of cross-cutting issues and opportunities. Articulating and understanding these issues are important PAIR activities. The PAIR-T white paper and workshop brought starkly into focus three major problem areas confronting the transportation sector in the 21<sup>st</sup> century:

- *Physical:* Historical under-investment has led to massive decay, deterioration, and obsolescence. The data suggest that comprehensive and effective renewal of the nation's basic surface transport infrastructure could come with a price tag of substantially more than \$600 billion for maintenance of the just the status quo.
- *Cultural:* Liability concerns, outdated procurement practices, and industry fragmentation discourage innovation. There is a very real perception that innovation is risky. Such disincentives are impeding technological advances in transportation in the U.S. As a result, global competitors are quickly gaining a market advantage.
- *Institutional:* Conservative and incremental approaches have led to piecemeal and ineffective solutions. In spite of the fact that well over a dozen federal agencies have instituted programs that address some aspects of materials and methods research, no single program has fundamentally changed the way we plan, design, finance, and build the nation's basic transportation infrastructure, such as highways and bridges. If we continue down this same path, there will be few, if any, incentives for material suppliers to invest in new plants and processes to improve infrastructure technologies and products.

Issues unique to the transportation sector are thoroughly explored in the PAIR-T white paper.

The broader PAIR partnership includes the telecommunications, energy, and water/wastewater sectors as major non-transport infrastructure elements. Although the non-transport elements of the nation's infrastructure generally suffer less from massive decay and deterioration than does the transport sector, there are serious cultural/societal and institutional impediments to renewal and advancement of non-transport-related infrastructure as well.

In the telecommunications sector, there is no clear, universally accepted model of systems interdependence despite the exploding growth in demand for reliable and fully integrated computing and telecommunications services and technology. In addition, the state of the art of the technologies and systems that support and safeguard telecommunications and computing infrastructure is lagging far behind the rate of technology innovation per se.

In the energy supply and distribution sector environmental regulation, rather than technology, is the central issue. The uncertainty of the direction and scope of future regulation in the energy sector has increased industry anxiety about major business decisions. Protection of system assets from catastrophic events is a serious public welfare and national security problem. Transmission and distribution system access and capacity issues will loom large in the future. Technologies such as renewables, micro-turbines, and fuel cells require greater research funding to make them competitive in more energy markets.

In the water supply and wastewater treatment sector, the costs of providing a reliable, high-quality product are skyrocketing. Privatization of the industry would drive product delivery costs down, but there is tremendous institutional resistance to privatization. The reason is that such services and related infrastructure are regarded as sacred public trusts. Another, more ominous, problem on the horizon is the uncertain availability of adequate water supplies. While preserving and improving the quality of our nation's rivers, lakes, and streams is a critical near-term concern, the question of whether there will be sufficient quantities in the future is even more basic.

As these sector-specific problems suggest, fundamental societal and cultural choices will have enormous impact on the nation's infrastructure in the 21<sup>st</sup> century and beyond. Key issues affecting the future of the non-transport elements of the nation's infrastructure are discussed below.

## **Changing Societal Needs for Infrastructure**

### *Urban Growth and Infrastructure Priorities*

Over the next two decades more than half the world's population will be centered in large urban areas. The current value of just the aggregate U.S. investment in infrastructure likely exceeds \$7 trillion, more than \$25,000 per person. Consider just one component of this investment: pollution control. Over \$100 billion has been invested in this country to respond to the requirements of the Clean Water Act of 1972 alone. Another \$100 billion has been invested in non-water-related environmental controls. According to the USEPA, more than \$400 billion in new investment will be required over and above that needed for maintaining and repairing the nation's existing environmental infrastructure. Worldwide pollution control expenditures *for water resources protection alone* could reach over \$500 billion annually by 2001. Competing demands for limited infrastructure dollars are forcing society to set priorities as never before.

The U.S. investment in infrastructure to support urban development over the past decade fell far short of actual needs. Current U.S. spending on advancement of civil infrastructure--in 1997, approximately \$115.1 billion, including \$78.8 billion in public investment--is shockingly low relative to other developed economies. Private and public sector R&D supporting the development of better, cheaper, and faster infrastructure technologies and practices is less than 0.5 percent of the annual expenditure for new construction and renovation, far below the approximately 3.5 percent average of other mature U.S. industries.

Right-of-Way conflicts are increasing the complexity and expense of implementing repairs or building new infrastructure. This largely hidden cost has been identified by public works organizations as a major problem. As transport and utility corridors become more crowded, streamlining their use to avoid accidental damage and costly delays in repair and replacement will be essential. Provisions in the recently enacted TEA-21 mandate study of the extent to which states have used available technologies, such as subsurface utility engineering, early in the design

of Federal-aid highway and bridge projects to eliminate or reduce the need for or delays due to utility relocations.

The massive job of renewing and advancing the nation's infrastructure cannot be undertaken seriously without specifying priorities for limited funds and developing a clear strategy for marshaling and allocating resources. Prioritization must be accomplished in a cooperative framework that engages all sectors of the economy in the dialogue. This will require an unprecedented level of collaboration and synergy on research and development (R&D), demonstration, testing, evaluation, and, technology transfer.

### *Environmental Consciousness and Sustainability*

Environmental protection and sustainability are now the watchwords of the environmental movement. Expressions like NIMBY (not in my back yard) and BANANA (build absolutely nothing anywhere near anything) developed because interest groups and urban communities needed to communicate the pressures of overcrowding, territoriality, and environmental resource degradation to public officials and frustrated developers.

Natural resources protection is a major issue facing all economic sectors. Urban water supply quality is a highly visible example of heightened environmental awareness that unfortunately pits the public against government in regard to capital improvements priorities. The encroachment of urban development on critical groundwater recharge zones and surface watersheds has put the quality and quantity of our water resources in jeopardy. The principal culprits are uncontrolled storm water runoff and the rapid growth in the proportion of impervious to natural surfaces.

Some experts believe that the storm water treatment technologies on the market today do not, and cannot provide adequate treatment for water quality protection. They insist that either advanced "treatment trains" that link multiple technologies together or sophisticated (and expensive) treatment approaches based on state-of-the-art wastewater treatment plant technologies are required. Innovative technologies to treat what has been called "ultra-urban" runoff have emerged over the last 5 years or so, but substantial improvements in monitoring methods and performance verification of these technologies remains a pressing need for water quality protection.

Energy consumption and America's energy future also appear prominently on the national environmental radar screen. Innovative renewable energy sources, energy conservation strategies, process energy recovery, and integrated energy resource planning will become the linchpins of economic prosperity when petroleum prices rise. Barring the widespread acceptance and practicability of cold fusion, hydrogen, and nuclear power sources, petroleum prices are almost certain to jump in the next century even without the threat of a Middle East conflict. Current infrastructure design practices discourage the explicit accounting of integrated and life cycle effects of imbedded future energy costs associated with complex engineered systems beyond specific aspects of plant operations. The infrastructure industry must address the energy aspects life-cycle costs and tradeoffs in a comprehensive and coordinated manner.

Developing a sustainable U.S. economy will require the careful balancing of public policy, technology innovation, and financial resources. Recycling, reuse, and reliance on renewable resources can only go so far toward this goal. Urban growth will continue to be both a space allocation and an environmental resource depletion problem until new concepts of urban planning and their influences on urban infrastructure advancement are explored.

## *Impacts of the Information Age*

Innovations in data transmission, processing, and access have caused an explosion in telecommuting. The virtual office is no longer a futuristic concept. Small business, the backbone of the American economy, is already leading the way. Small businesses employ a large majority of the nation's workforce. The eventual technological impacts on infrastructure needs in transportation systems and telecommunications that telecommunication innovations *could* have are apparent. The issue is whether big government and big business will fully embrace the potential opportunities afforded by the technology.

Early in this century, innovations such as the skyscraper and elevators allowed face-to-face interaction, considered indispensable to American business. The telephone was merely an enhancement to this activity. Today, however, the economic and social costs of traveling between points on a map are self-evident. The potential of concurrent engineering technologies in a virtual communications environment needs to be thoroughly explored. Virtual interfacing is partly a technology issue and partly a business practice issue.

## **Cultural and Institutional Issues**

### *Deregulation and Restructuring*

Mature U.S. industries, such as railroads, electric power, automotive, electronics, telecommunications, and banking, are in a period of massive reorganization and restructuring. Some, like the telecommunications, rail, and banking industries are consolidating, and others like the electric power industry are fragmenting.

On the one hand, this phenomenon has reduced the price of goods and services on both the supply and demand sides of the economy. Independent power producers, for example, have been able to cut the time typically required to come on line in half over the last five years. Technological innovations and increasing economies of scale have dramatically lowered the costs of consumer electronics, such as computers and cell phones. On the other hand, deregulation and restructuring have also placed greater burdens on the nation's infrastructure. In the electric power industry, for example, restructuring is expected to exacerbate the problem of marginal transmission assets. The demand for transmission services will increase, as long-distance power wheels become more common, leading eventually to continental transactions. The challenges confronting transmission owners and operators are those of maintaining and improving reliability of transmission, while demand increases and transmission capacity is held essentially constant.

Deregulation and restructuring are changing the organization and delivery of goods and services in fundamental ways. The potential impacts of infrastructure capacities and performance on how the nation will conduct business in the future need to be investigated before large sums are committed to particular courses of action.

### *Privatization*

Privatization may be the single most important business force for long term advancement of technology and management innovation in historically government-owned industries, such as the water and waste water industry. Yet, privatization is almost non-existent in the U.S. There are enormous institutional barriers to ceding control over what is regarded as a unique and sacred public trust. The political and institutional resistance to privatization in the water utilities industry, for example, will be difficult to overcome. It certainly was in the utility industry, which

is only now going through the painful throes of a massive restructuring. The concepts of stranded costs and cost recovery are one issue, but there are deep-seated institutional and legal issues, and jurisdictional issues as well.

If the trend toward privatization achieves a foothold in this country, the prospects for rapid innovation will be greatly enhanced. This can only occur, however, if current legal perspectives on liability and risk-based management are changed to reflect the burdensome costs of overly conservative business practices.

### ***Systems Integration***

In the future, the functions of networked utilities, such as electricity, gas, water, and communications, may be merged into a single utility company. Even well short of mergers and acquisitions, utilities may partner with each other on activities such as meter reading, maintenance, and system operations. From an infrastructure standpoint, the integration of utility functions may allow for the design and construction of dedicated utility service corridors containing superconducting transmission and distribution; fiber optic communication systems for telephony, video, data transmission, and audio entertainment; gas pipelines, and water mains. Metering and billing functions would be integrated and automated. New materials will be developed to repair, replace, and support an aging pipeline infrastructure. In addition to the "undergrounding" technology described in later sections of this paper, work is needed to develop advanced metering technologies, standards for data interchange, and billing and metering systems.

### ***Disincentives to R&D***

The repeal of the R&D Investment Tax Credit has a debilitating effect on the flow of private money to R&D activities. This impact has been particularly acute for long-lead technologies in mature industries, such as water and waste water. The industry risk/reward ratio is skewed against R&D. When there is public funding, performance standards and life cycle cost-based criteria are needed to allow acceptance of proprietary products.

Because of the speculative nature of R&D and the concomitant financial risks, collaborative partnerships between government, industry, and academia are becoming more critical to technology innovation. The costs and the risks of R&D require a focused pooling of resources across all economic sectors. Over the last 10 years, broker organizations, such as non-profit private sector associations, have emerged to facilitate the collaboration of historically competitive interest groups to leverage available funds for research vital to the nation's infrastructure and national security.

### ***Critical Infrastructure Protection***

"Critical infrastructures" are those that directly affect the nation's economic prosperity and national security. Threats to critical infrastructures include physical disruption, "cyber threats," and inherent system complexities and interdependencies. Infrastructure is becoming increasingly dependent on computers and telecommunications. The most important point of vulnerability for telecommunications is the increasing interdependency of the Public Telephone Network (PTN). The PTN, in turn, depends on electrical power for operations and on telephone lines and fiber optic cables. The PTN is increasingly software driven, and remotely managed and maintained through computer networks. One well-publicized example of vulnerability associated with out dependence on computers is the "Year 2000" problem ("Y2K"), which, if not corrected, could have disastrous consequences on the economy and on national security. The U.S. is

leading the effort to resolve this problem and the rest of the world lags far behind. Deregulation of the telecommunications industry will markedly increase the number of access points, increasing opportunities for interruptions. In addition, disaster risk reduction has emerged as a major U.S. and global priority. The seismic safety of vital transmission systems, such as natural gas pipelines, is critical to national security and the economy.

Organizations responsible for safeguarding communications network need to come together with the user and supplier communities to identify infrastructure vulnerabilities and map out strategies for protection of critical infrastructure. Innovations in materials science, structural engineering, and subsurface utility engineering that could mitigate the impacts of natural disasters need to be integrated in a directed effort to predict and prevent debilitating damage.

### **Technological Opportunities**

Innovations in information and telecommunications technologies afford opportunities to greatly enhance the effectiveness of the nation's civil infrastructure. Satellite global positioning (GPS) for precise site measurement is reducing the costs of design and construction. Advanced instrumentation for automated controls, infrastructure condition diagnostics, fault detection, and quality control hold great promise for advancing the engineering aspects of the nation's infrastructure. Space-age materials, such as advanced polymers and composites can greatly extend the performance, reliability, and durability of infrastructure projects, thereby reducing life-cycle costs.

Innovation opportunities that draw on the growing convergence of fiber optics, fiber electronics, microelectronics, digital electronics, and wireless access methods are changing the industry. The industry is using scanning, global positioning and trenchless technologies to locate underground cable without resorting to traditional excavation. The cross-cutting implications of these technologies for other infrastructure sectors are staggering; they could radically transform the way the sewerage systems are upgraded, gas lines are expanded, and roads and bridges are repaired.

Innovative knowledge systems and new technology applications may be just as important to infrastructure performance as technology itself. One such system is fully integrated and automated project processes, or FIAPP. This approach focuses on the seamless life cycle integration of all project activities. The system is based on automated knowledge-based decision aids, application of institutional intelligence, and common databases and formats. The computer-integrated knowledge system (CIKS) is a complementary approach to FIAPP in the construction industry. The CIKS network now under development in a collaborative effort by CONMAT, ASTM, NIST, and other groups will provide universal electronic access to distributed data and smart life-cycle management capabilities for advanced construction materials development. Together with the NIST computer-aided design (CAD) common standards development effort, FIAPP and CIKS have the potential to revolutionize civil engineering and construction.

## **BUILDING THE PARTNERSHIP**

The Partnership must combine private and public resources and serve both private and public interests. Building the Partnership will involve setting clear objectives and devising programs to meet those objectives without attempting to take on the work that others are doing.

## Goals and Objectives

PAIR's primary goal is to accelerate innovation in the construction, maintenance and repair of our nation's infrastructure. Other groups such as Rebuild America have focused the public's attention on the fundamental need for infrastructure renewal and repair. In addition to highlighting performance capabilities of innovative materials and processes, much of the Partnership's effort will also address non-technical obstacles that slow the pace of innovation and discourage industry from commercializing promising technologies. Within this context, PAIR will pursue four specific and inter-related objectives:

- ***PAIR will work to nurture a national constituency*** committed to development and use of innovative technologies for infrastructure and its renewal. This constituency will necessarily include the general public; there must be a "grass-roots" understanding of the importance and potential of infrastructure advancement if business and government are to make and maintain their commitment.
- ***PAIR will work to create joint private and public sector R&D initiatives*** to aggressively develop and commercialize these new technologies. PAIR itself will not participate in these initiatives, but rather will serve as matchmaker and broker to bring together the partners who will do the hard work of innovation. PAIR will monitor progress and recommend appropriate additional new efforts.
- ***PAIR will work to identify and reduce the obstacles*** impeding rapid commercialization of innovative technologies. Experience has shown that such issues as procurement policies, liability and risk management concerns, and workforce education and skills can encourage or subvert innovation; other obstacles become apparent as new ideas are proposed and tested. Business and government working together must assure that new technologies are achieved with an appropriate balance of public and private costs and benefits, now and into the future
- ***PAIR will work to give recognition to innovators*** and to showcase new technologies that advance infrastructure. Such recognition not only rewards the work of those involved in developing useful new technologies, but also may inspire others to make the effort to achieve other advances.

## Overall Implementation Strategy

Much is now being done to advance infrastructure, as reviewed in a later section of this paper, and PAIR's planners recognize that many programs already are in place. The Partnership's strategy is to build on existing programs, to encourage a coordination of effort and a leveraging of resources, to create a climate that fosters private- and public-sector collaboration. PAIR will do this in two key ways:

- ***PAIR will provide its participants a "bully pulpit"*** for drawing attention to the nation's needs and opportunities for research for infrastructure advancement and renewal. The Partnership will disseminate informed and provocative statements on current issues of infrastructure innovation, as well as information about ongoing and planned research, deployment, and revitalization programs. The Partnership will work to expand these programs' effectiveness by encouraging greater collaboration and leveraging of funds between and among public and private sector institutions. PAIR's efforts in this area may ultimately spur business and

government to commit more funding to develop innovative technologies for infrastructure revitalization.

- ***PAIR will provide the forum, expertise, and assistance*** to business and government leaders undertaking to develop new programs for infrastructure R&D, demonstration, testing, evaluation, and technology transfer. PAIR will not assume management responsibility for these programs, but rather will be a vehicle for their planning and coordination.

We envision that these complementary strategies will evolve as a broader constituency is attracted to infrastructure innovation. The broad scope and diversity of this constituency demands flexible priorities and realistic expectations.

## **Participants**

The Partnership now is drawing together leaders from business and industry, government at all levels, and non-governmental organizations (e.g., public interest, trade, and professional associations), and academia. PAIR's private-sector participants to date include representatives from banking, insurance, manufacturing, communications, transportation, A/E design community, and facility operations and management, as well as other industries that supply, use, and depend on infrastructure. Federal participants will be provided by the Subcommittee on Construction and Building of the National Science and Technology Council (NSTC). Academic participants will be guided through such authoritative institutions as the National Science Foundation's Institute for Civil Infrastructure Systems. The Civil Engineering Research Foundation (CERF), the non-profit research affiliate of the American Society of Civil Engineers (ASCE), serves as Secretariat to the PAIR Executive Committee.

PAIR will seek the broadest possible involvement in its initiatives. The Partnership will be successful only to the extent that it provides to its participants benefits commensurate with the time and other resources participation entails. There are three compelling reasons that warrant a high level of participation in the Partnership:

First, as a forum bringing together leaders of business and government, PAIR will facilitate the exchange of views that helps to identify and resolve difficult issues of infrastructure advancement. The exchange will help also to assure that key economic, technical, and political matters that encourage or impede the successful commercialization of promising new technologies are dealt with swiftly and effectively.

Second, the PAIR forum will also provide opportunities for industry leaders, public officials, academic researchers, and public interest groups to form new collaborations to seek innovation for infrastructure advancement and renewal. Joint ventures, outreach programs, new institutions, and other specific initiatives will grow out of the Partnership to pursue breakthroughs in infrastructure innovation.

Finally, PAIR's participants will gain exposure to new ideas and developments in fields outside their own primary area of business. Experience shows that such exposure encourages new applications of technologies and opens market opportunities.

PAIR is conceived as an inclusive initiative; its participants must span the range of stakeholders in infrastructure advancement. Each participant necessarily will endorse the basic concept of the Partnership and its aims and commit resources to its implementation and development.

Individuals and organizations from all segments of the stakeholder community will be invited to participate, including

- Owners, financiers, developers and custodians of public and private infrastructure facilities, such as local departments of public works, airports, port authorities, water companies, toll authorities, gas and electric companies, telecommunications operators, insurance companies, investment and commercial banks, engineering designers, construction companies, state transportation agencies and construction materials and equipment manufacturers
- Substantial suppliers and users of infrastructure, such as manufacturers, freight shippers and transportation-services companies, petroleum producers and refiners, vehicle manufacturers, information-technology producers, and instrumentation manufacturers
- Research, programmatic, and regulatory agencies, such as units of the U.S. Departments of Commerce, Energy, Defense, and Transportation, Environmental Protection Agency, and National Science Foundation, as well as agencies representing potential beneficiaries of infrastructure advancement, such as the U.S. Departments of Education, Housing and Urban Development, Labor, and Justice
- Industry and trade associations, labor organizations, and other non-governmental organizations such as the Electric Power Research Institute (EPRI), the American Gas Association (AGA), the Telecommunications Industry Association (TIA), the American Association of State Highway and Transportation Officials (AASHTO), the American Public Works Association (APWA), the American Water Works Association (AWWA), the Water Environment Research Foundation (WERF), the Council on Competitiveness, the National Association of Manufacturers (NAM), and many others
- Research and development institutions, colleges and universities, and other educational and research organizations

### **Partnership Management and Resources**

PAIR does not envision or wish to create a “new” program or entity to supercede existing public or private sector programs. PAIR will not fund or manage collaborative research programs. Rather, PAIR will promote and encourage collaborative research efforts and the effective leveraging of limited resources. Its success will ultimately be measured by the acceleration of innovation in products and services as developed by a growing variety and scope of private-public partnerships. We estimate that these partnerships could invest as much as \$1 billion per year in research, development, and deployment, a doubling of current investment commitments.

The President established the National Science and Technology Council (NSTC), a cabinet-level group charged with setting Federal science and technology policy, to coordinate and prioritize R&D and deployment strategies across a broad cross-section of public and private interests. It recently reorganized its committee structure into four research and development committees, including the Committee on Technology. Under the Committee on Technology the Subcommittee on Construction and Building coordinates and defines priorities for Federal research, development and deployment related to the industries that produce, operate and maintain constructed facilities, including buildings and infrastructure. Fourteen Federal agencies are represented on the Subcommittee.

The Subcommittee is involved in partnerships with industry and academia such as PAIR to accomplish its goals through research, development, and application of innovative products and practices. For example, the Subcommittee is supporting a project being performed by the National Conference of States on Building Codes and Standards (NCSBCS), and the Partnership for Advancing Technology in Housing (PATH) to streamline the building regulatory process.

PAIR's organizational structure and goals are illustrated in the figure on the following page. We envision that an all-volunteer PAIR Executive Committee (PAIR ExCom) will be established by the principal segments of the stakeholder community: government, industry, associations and foundations, and academic institutions. ExCom members may be nominated by any of the Partnership's participants and elected by the Partnership as a whole. The NSTC Subcommittee on Construction and Building, which is composed of representatives of 14 federal agencies, will be represented on the Executive Committee. The ExCom will be responsible for development and administration of PAIR's operating policies, including its fiscal and administrative procedures. The ExCom will also provide guidance on all major PAIR initiatives, such as the development of infrastructure-performance metrics, research agendas, and educational and fund-raising campaigns.

### ***CERF as Partnership Secretariat***

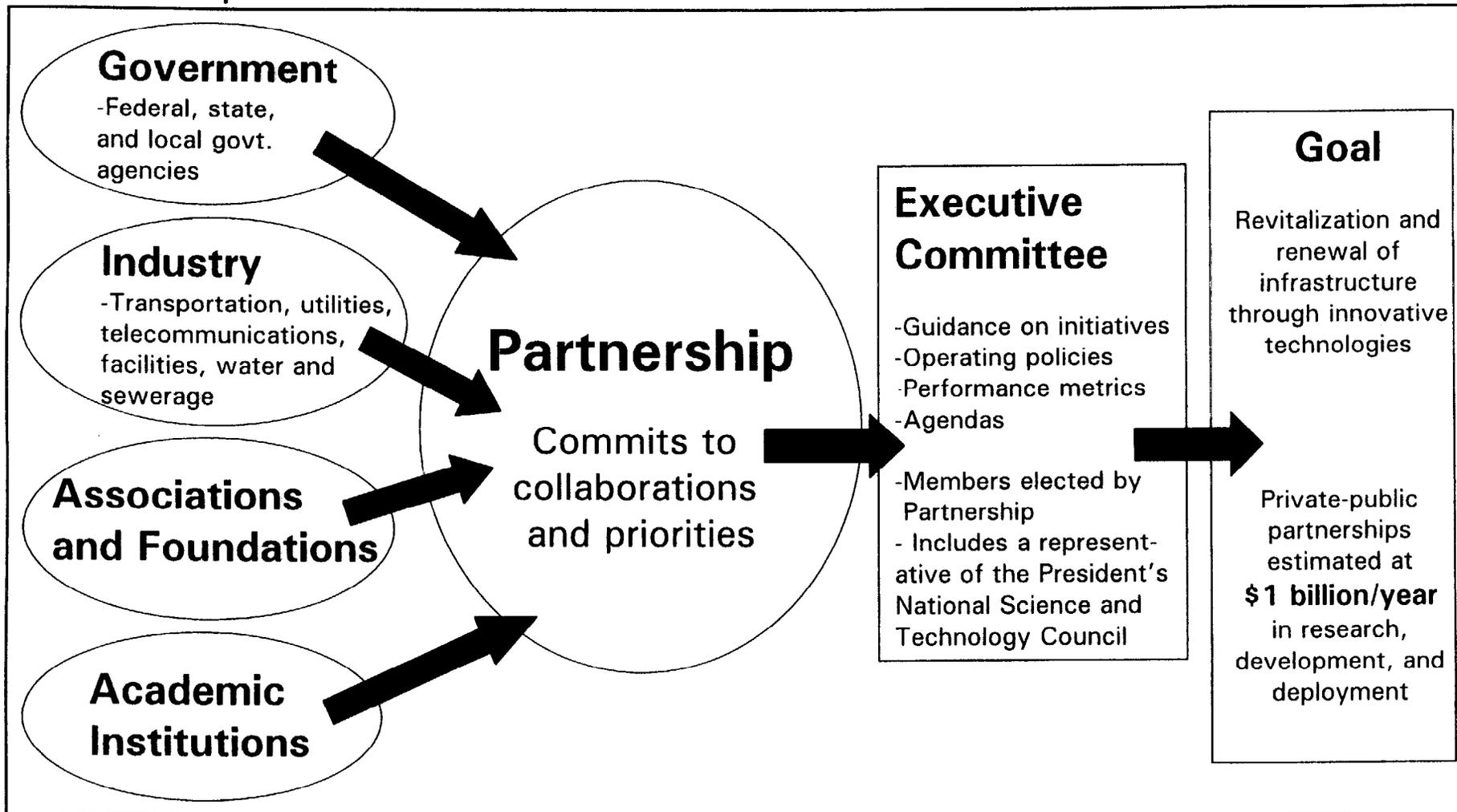
The Civil Engineering Research Foundation (CERF) will serve as Secretariat to the PAIR Excom. In this role, CERF will facilitate, integrate, and collaborate with all partnership members. CERF will, for example, be responsible for convening the Committee's meetings, disseminating information about PAIR to the general public, coordinating the day-to-day activities of PAIR's initiatives, and other administrative tasks as assigned by the Executive Committee. As PAIR's Secretariat, CERF will facilitate collaboration and coordination among the Partnership's members, but the real direction of PAIR will come from industry and state and local government: these participants are the technology buyers and the stewards and beneficiaries of the nation's infrastructure. The estimated costs for the ExCom and Secretariat activities are estimated to be \$1 million per year as PAIR gets fully underway. These operating costs are but one-tenth of one percent of the amount of projected RD&D collaborative activities that are expected from the new focus developed through PAIR.

CERF was established in 1989 by the American Society of Civil Engineers (ASCE) as an independent 501(c)(3) nonprofit organization, to coordinate research and innovation for the design and construction industry. CERF brings together suppliers and consumers, academics and practitioners, owners and users to facilitate the transfer of information and technology into practice. CERF's sole agenda is encouraging the rapid commercialization and integration of new technology and practices of benefit to the design and construction communities. CERF currently serves as the Secretariat or focal point for a number of national programs to accelerate advanced materials use and promote innovative technologies.

CERF is well known for its Innovation Centers, which it operates in the areas of highways, infrastructure, buildings, and the environment. The Highway Technology Evaluation Center (HITEC), developed in partnership with the Federal Highway Administration, is a nationally recognized service center and clearinghouse for implementing highway innovation, evaluating products, materials, services, equipment, and systems such as composite bridge decks, earth retaining systems, and heated pavement systems. The Environmental Technology Evaluation Center (EvTEC), established through a cooperative agreement with the U.S. Environmental Protection Agency (EPA), is designed to promote the acceptance of innovative environmental management technologies. The Civil Engineering Innovative Technology Evaluation Center

# Fig. 1: Building the Partnership

Partnership for the Advancement of Infrastructure and Its Renewal (PAIR)



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## SECRETARIAT: CERF

Facilitate and coordinate, disseminate information, administration

*Estimated operating costs for Executive*

*Committee and Secretariat: \$1 million/year*

(CEITEC) provides performance evaluations services for a wide spectrum of innovative technologies, with particular emphasis on public works, military applications, and trenchless technologies. In collaboration between CERF and the National Evaluation Service (NES), NES-BIC serves the building and residential housing industries. NES-BIC was formed through a partnership of industry and government stakeholders who recognized the need for an effective, expedited means to bring building innovation to the marketplace. The Center provides an independent technical evaluation service for building technologies for all types and can be used by innovators, designers, or those who own and operate facilities to gain credible information on the performance of new technology.

With all of the Innovation Centers, evaluations are planned, conducted, and overseen by panels of technical experts who represent the entire stakeholder community of potential users or purchasers of the products or technologies.

In addition to the Innovation Centers, CERF serves as Secretariat for the high-performance CONstruction MATerials and systems program (CONMAT). CONMAT is a cooperative industry-government partnership that works closely with universities to accelerate the commercialization of innovative construction materials and systems for the erection, repair, and retrofit of structures

### **Measures of Partnership Performance**

The most tangible evidence of the success of PAIR's initiatives will be new technologies bringing improved performance and economies to the nation's infrastructure. From a worldwide perspective, the economic benefits of innovative technologies for higher quality and more economical infrastructure will be trillions of dollars over the next 10 years. In addition, the advancement of infrastructure's performance will yield broad public benefits, e.g., reduced congestion, greater safety and reliability, new services, lower costs. PAIR will produce regular reports assessing the outcomes of the Partnership's activities.

Over the near term, however, more immediate measures of PAIR's success will be crucial. For example, publications and citations in the press and public presentations will provide evidence of PAIR's influence to increase understanding among business leaders, elected officials, and the public at large of how infrastructure innovation contributes to economic competitiveness, national security, and environmental stewardship. Each new PAIR initiative that brings together private- and public-sector participation to achieve specific infrastructure innovations will be evidence of the Partnership's progress toward its primary goal. In addition, the pulling together of local, state, and federal government resources devoted to advancement of products and practices for infrastructure maintenance and renewal will improve the efficiency of resource use. PAIR will monitor these several measures of PAIR's results performance against stated objectives as well.

More specific Partnership performance measures will be defined by the PAIR ExComm after initial "groundbreaking" is underway. Key areas for which performance measures are likely to be established are discussed below in "PAIR Initiatives Beyond First Steps."

### **TAKING THE FIRST STEPS**

One of the early tasks now facing the Partnership will be to initiate modest educational and fund-raising campaigns within the private sector to complement public funds already earmarked for PAIR secretariat activities. Many current and planned government programs have objectives compatible to PAIR's, and these programs may be sources of seed funds for the Partnership.

Combinations of new leveraged private and public sector support, both direct and in-kind, will then be the means for the growth of PAIR's initiatives.

### **Existing Complementary Programs**

PAIR is being built on the foundations of earlier public-private partnerships. For example, CERF's HITEC was funded in part by FHWA under the Intermodal Surface Transportation Efficiency Act (ISTEA); future federal legislation could include funding for PAIR-initiated programs. The National Institute of Standards and Technology (NIST) has recently established the Partnership for High-Performance Concrete Technology (PHPCT), which will work in association with PAIR to speed the application of innovative concrete technology to infrastructure. The President's National Science and Technology Council Construction and Building Subcommittee is already working with PAIR and will continue to do so in PAIR's effort to use workshops and publications to gain broader public understanding and support for the Partnership's aims.

Largely private-sector programs that might similarly coordinate with PAIR include those of the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), the American Water Works Association Research Foundation, and others.

### **Consensus for Action from the PAIR Workshop**

Building on the efforts of existing complementary programs and the first transportation-focused workshop (PAIR-T), a second workshop, sponsored by the President's National Science and Technology Council's Committee on Technology and CERF, was convened on June 30, 1998 and focused on the telecommunications, energy infrastructure, and water supply and sewerage sectors. The second workshop was attended by a diverse group of professionals who were predominantly from the private sector and who typically do not cross paths in the normal course of business. Perhaps the most exciting aspect of these new PAIR stakeholders was that many of the attendees had never before been actively involved in focused discussions about the future of the national infrastructure.

Workshop plenary session speakers challenged large corporations, designers, builders, owner/operators, equipment and material suppliers, public works planners, financial professionals, management consultants, and other stakeholders to think outside the traditional engineering envelope as they developed the PAIR agenda. Workshop participants concurred that PAIR is an essential element in a national effort to transform the infrastructure through an unprecedented level of collaboration in research and development (R&D) that dramatically improves technologies used for infrastructure revitalization. All of the presentations to the plenary group echoed the need to engage a far wider public in the renewal and advancement of infrastructure than ever before.

Workshop participants recommended that small groups of PAIR stakeholder volunteers who will define the directions the Partnership should take and lead the effort to renew and advance the nation's infrastructure. CERF will facilitate the work of the workshop attendees and other stakeholders in developing and prioritizing strategic ideas and laying out courses of action in a detailed implementation plan. In addition, a solid coalition of stakeholders to champion the PAIR vision of a renewed and globally competitive basic national infrastructure must be established before significant public and private resource pools can be tapped effectively.

Several recurrent themes arose during the course of the PAIR workshop. Chief among them were developing a shared vision of the future, recognizing the interdependence of infrastructure systems, financing infrastructure renewal and advancement, the need for regulatory change, and acceptance of the responsibility for environmental stewardship. One of the most important outcomes of the breakout sessions was strong agreement that both a detailed PAIR implementation plan be developed for each sector and that PAIR members increase public awareness of the national infrastructure.

The initial tasks outlined below, therefore, reflect the need to develop action plans and establish public image and continued visibility.

One of the key near-term objectives of PAIR is to develop a detailed implementation plan, or "road map." This approach will build on the issues raised and discussed at the April and June PAIR workshops, as well as the strategies outlined in the respective white papers. The road map will provide a level of detail that will allow PAIR to attract specific commitments from private and public sector partners and expand the breadth of the PAIR constituency.

Expert constituency working groups will be recruited to draft the road map plan. The volunteer membership of the working groups will identify specific tasks to be accomplished. The road map will describe how PAIR partners can support infrastructure sectors of interest. The road map will focus on how PAIR can specifically assist each organization in the broadening of the technical scope, management, and financing of these programs.

A PAIR web site will be installed on the Internet. The PAIR page will present a basic description of PAIR, an executive summary of the PAIR workshops, the PAIR white papers, and a listing of active PAIR participants. The site will showcase all PAIR-relevant programs supported by U.S. federal agencies, as well as other public and private sector organizations.

In addition to increasing the public's awareness of PAIR through its Internet site, efforts will be made to promote PAIR through many of its related programs focusing on outreach and collaboration. For example, as part of the PAIR road map/implementation plan, PAIR would contribute to the August 2000 International Research Symposium that is entitled "Symposium 2000: Moving Innovation into Practice—Driving Change for a Sustainable Future."

### **PAIR Initiatives Beyond First Steps**

Plans will be developed more fully as the PAIR initiative begins to grow. PAIR's participants to date have recommended a number of key areas to receive near- and medium-term attention. Setting specific performance measures for these key areas will be a defining step forward for the Partnership:

- Recruiting and involving a broad coalition of other organizations
- Developing a clear message to build public understanding of needs and benefits for improved infrastructure and support for infrastructure advancement
- Facilitating R&D agenda and priority development
- Pre-qualifying and pre-approving new technologies to reduce liability
- Developing appropriate measures of infrastructure performance
- Benchmarking the state of foreign and domestic technology
- Addressing key non-technical obstacles to innovation, e.g., procurement practices, litigation risks, entrepreneurs' incentives, funding for research and demonstrations

- Promoting case studies and impact assessments
- Stimulating showcase projects for innovation

A key challenge is developing a stable source of funding for PAIR initiatives. The success of early education and fund-raising campaigns will largely determine the Partnership's subsequent course. Overcoming government budgetary constraints is a significant challenge and will require the concerted effort of the both the public sector and the private sector in forging new, cost effective partnerships that leverage scarce funds effectively.

The Partnership's success will depend on the willingness of business and government to commit real resources to PAIR's initiatives and to the consequent adoption of new technologies advancing infrastructure. We envision that success in establishing the Partnership could stimulate investment into PAIR-initiated programs amounting to perhaps \$1 billion annually within the next decade; this admittedly optimistic target would represent approximately a 100 percent increase of the funds annually spent on infrastructure-related R&D in the United States.

As reviewed earlier in this paper, there are cultural and institutional obstacles to the success of PAIR and its objectives. The business of infrastructure is highly fragmented, making unified action at best difficult, and the public works and civil infrastructure communities, compared to other sectors of the economy, are historically conservative and hesitant to take risks. Such a stance is perhaps understandable in terms of the issues of public safety and low entrepreneurial reward pervading much of the infrastructure, only if "market pull" matches the "technology push" will innovations rapidly and routinely penetrate and be accepted in the marketplace. PAIR is now largely a dream. Its realization will demand the best from those who stand to gain the most from turning this dream into reality.

## ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AGA	American Gas Association
APWA	American Public Works Association
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BANANA	Build absolutely nothing anywhere near anything
CAD	computer-aided design
CEITEC	Civil Engineering Innovative Technology Evaluation Center
CERF	Civil Engineering Research Foundation
CIKS	computer integrated knowledge system
CONMAT	high-performance CONstruction MATerials and systems program
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EvTEC	Environmental Technology Evaluation Center
FIAPP	fully integrated and automated project processes
GPS	global positioning system
GRI	Gas Research Institute
HITEC	Highway Innovative Technology Evaluation Center
ISTEA	Intermodal Surface Transportation Efficiency Act
NAM	National Association of Manufacturers
NCSBCS	National Conference of States on Building Codes and Standards
NES	National Evaluation Service

NES-BIC	National Evaluation Service- Building Innovation Center
NIMBY	Not in my back yard
NIST	National Institute of Standards and Technology
NSTC	National Science and Technology Council
PAIR	Partnership for the Advancement of Infrastructure and its Renewal
PAIR-T	Transportation Component of PAIR program
PATH	Partnership of Advancing Technology in Housing
PHPCT	Partnership for High-Performance Concrete Technology
PTN	Public Telephone Network
TEA-21	Transportation Equity Act for the 21 <sup>st</sup> Century
TIA	Telecommunications Industry Association
WERF	Water Environment Research Foundation
Y2K	Year 2000 problem