Strategic Planning Document—Transportation R&D National Science and Technology Council

March 1995

PREFACE

This summary of federal transportation research and development priorities has been prepared for the National Science and Technology Council (NSTC) by the NSTC Interagency Coordinating Committee on Transportation Research and Development (R&D) and the White House Office of Science and Technology Policy (OSTP). The plan reflects the initial efforts of the Committee to assess federal research and to develop long-term R&D programs integrated across agencies in specific transportation-related areas of common interest. It is based primarily on materials developed by the subcommittees and working groups, working within the framework established by the full Committee in its strategic budget guidance report presented to NSTC in April 1994. The summary was compiled from subcommittee submissions by staff of the U.S. Department of Transportation (DOT) Volpe National Transportation Systems Center under the direction of Noah Rifkin, executive secretary of the Committee and DOT director of technology deployment, and by OSTP. The subcommittee reports contain extensive additional detail concerning agency programs, goals, issues, and resources. Efforts of the Committee in 1994, summarized in this document, focused on identification of perceived R&D gaps and opportunities. They provide the foundation for generation in 1995 of a detailed and comprehensive description of federal transportation R&D goals, plans, measures, budgets and priorities, including active coordination with other NSTC committees.

Subcommittees of the NSTC Transportation Committee are listed below. All chairs and executive agents are from the U.S. DOT; each subcommittee includes representatives from appropriate federal agencies.

INTERAGENCY COORDINATING COMMITTEE ON TRANSPORTATION RESEARCH AND DEVELOPMENT

CHAIR: Mortimer Downey, Deputy Secretary of Transportation
VICE-CHAIR: Wesley Harris, National Aeronautics and Space Administration
WHITE HOUSE CHAIR: Lionel Johns, Office of Science and Technology Policy
EXECUTIVE SECRETARY: Noah Rifkin, DOT, Chief of Technology Deployment

TRANSPORTATION SYSTEM ASSESSMENT I: Measurement, Monitoring, Characterization, and Modeling of System Performance

CHAIR: Tiruvarur R. Lakshmanan, Bureau of Transportation Statistics
EXECUTIVE AGENT: Robert B. Dial, Research and Special Programs Administration/Volpe Center

TRANSPORTATION SYSTEM ASSESSMENT II: Behavioral Sciences and Human Performance in Transportation Systems

CHAIR: Robert Clarke, National Highway Traffic Safety Administration
EXECUTIVE AGENT: Don Sussman, Research and Special Programs Administration/Volpe Center

PHYSICAL INFRASTRUCTURE FOR TRANSPORTATION (Infrastructure Renewal)

CHAIR: Tom Pasko, Federal Highway Administration
EXECUTIVE AGENT: Aviva Brecher, Research and Special Programs Administration/Volpe Center

INFORMATION INFRASTRUCTURE FOR TRANSPORTATION (Intelligent Transportation Systems and Telepresence)

CHAIR: Ana Sol Gutiirrez, Research and Special Programs Administration/Volpe Center

EXECUTIVE AGENT: Gary Ritter, Research and Special Programs Administration/Volpe Center

Working Groups:

- IVHS
- Rail
- Aviation
- Waterway
- Telecommuting
- Weather

NEXT-GENERATION VEHICLES

CHAIR: Richard R. John, Research and Special Programs Administration/Volpe Center

EXECUTIVE AGENT: Herbert H. Gould, Research and Special Programs Administration/Volpe Center

Working Groups:

- Aeronautics
- Partnership for a New Generation of Vehicles—Personal (Light-Duty) Motor Vehicles
- Space Launch
- Ships and Shipbuilding
- Trucks and Buses (Medium- and Heavy-Duty Motor Vehicles)

- Rail Vehicles (Intercity and Transit)

EXECUTIVE SUMMARY

This summary of federal transportation research and development priorities has been prepared for the National Science and Technology Council (NSTC) by the NSTC Committee on Transportation R&D and the Office of Science and Technology Policy. The plan reflects current progress in the ongoing effort to assess federal transportation research and to develop long-term research (R&D) programs integrated across agencies in specific transportation-related areas of common interest. The plan was compiled from subcommittee reports that contain extensive additional detail concerning agency programs, goals, issues, and resources. Efforts of the Committee in 1994 focused on identification of perceived R&D gaps and opportunities. The following objectives were developed for coordinated public and private R&D:

Physical Infrastructure for Transportation. Develop materials, design methods, nondestructive testing techniques, and other technologies for low-cost, long-lasting highways, bridges, airports, and other structures. Develop low-cost methods for nondestructive testing and repair of existing structures.

Information Infrastructure for Transportation. Apply the innovations available from the national information infrastructure to develop an intelligent transportation system that will ensure the safe and efficient intermodal operation of the nation's vehicles and physical infrastructure.

Next-Generation Transportation Vehicles

Aeronautics. Maintain world leadership in aircraft, engines, avionics, and air transportation system equipment for a safe, sustainable, global aviation system.

Space Launch. Ensure reliable and affordable access to space through a stronger U.S. space launch capability that meets the needs of the civilian, national security, and commercial sectors.

Personal (Light-Duty) Motor Vehicles. Renew leadership in automotive technologies through the development of a new generation of energy-efficient, low-emission vehicles that will preserve American jobs and improve American competitiveness.

Medium- and Heavy-Duty Motor Vehicles (Trucks and Buses). Ensure U.S. leadership in truck and bus technology by investing in improved materials, components, and design concepts and other technologies required for improved accessibility, energy efficiency, and environmental characteristics.

Rail Vehicles (Intercity and Transit). Position the U.S. as a world technology leader and primary exporter of rail-related equipment and services by facilitating technological innovation in rail vehicle design and construction and by introducing advanced materials and communications and control technologies that will result in improved performance and reduced costs.

Ships and Shipbuilding. Restore the competitiveness of the U.S. in shipbuilding, ship repair, ship design, and ship production in order to ensure a strong and competitive U.S. shipbuilding industry unsurpassed in building the finest and most complex vessels in the world.

Transportation System Design, Planning, Management and Operations

Transportation System Assessment Tools and Knowledge. Develop information required for government and industry managers to make effective decisions about the safe operation of existing transportation systems, as well as new investments.

Human Performance in the Transportation System. Define appropriate roles for the human-in-the-loop through human-centered automation, and improve the safety and competitiveness of American products through the integration of human performance principles and procedures and the application of new information dissemination, communication, and display technologies to transportation. These objectives provide the foundation for generation in 1995 of detailed and comprehensive description of federal transportation R&D goals, plans, measures, budgets, and priorities, including active coordination with relevant other NSTC committees.

The purpose of this report is to highlight ongoing federal research efforts in this science and technology field and to identify new and promising areas where there might be gaps in federal support. The report is intended for internal planning purposes within the federal agencies and as a mechanism to convey to the science and technology community the types of research and research priorities being sponsored and considered by the federal agencies. The Clinton Administration is committed to a broad range of high-priority investments (including science and technology), as well as to deficit reduction and to a smaller, more efficient federal government. These commitments have created a very challenging budget environment—requiring difficult decisions and a well thought out strategy to ensure the best return for the nation's taxpayers. As part of this strategy, this document does not represent the final determinant in an

overall Administration budget decision-making process. The research programs presented in this report will have to compete for resources against many other high-priority federal programs. If these programs compete successfully, they will be reflected in future Administration budgets.

OVERVIEW

Background

The United States owes much of its present prosperity to the efficiency of its transportation system. The flexibility and low cost of personal transportation in the United States is closely associated with most Americans' sense of personal freedom. But the system faces unprecedented demands for renewal. A fast-paced information-intensive economy is changing the places to which people want and need to travel, and new production and management methods are radically reshaping the shipping needs of businesses. At the same time, the nation's transportation system is expected to meet unprecedented standards for reliability, cost, timeliness, safety, and environmental impacts. Meeting these expectations, ensuring the vitality of a key part of national infrastructure, and enhancing the competitiveness of an enterprise that contributes directly or indirectly to the employment of nearly a fifth of American workers necessitates a vigorous research and development effort in which federal research and development (R&D) investment, coordination, and stimulation plays a critical role.

The U.S. transportation system includes 190.4 million automobiles, vans, and trucks operating on 3.9 million miles of streets and highways; 103,000 transit vehicles operating on those streets, as well as more than 7,000 miles of subways, street car lines, and commuter railroads; 275,000 airplanes operating in and out of 17,500 airports and landing fields; 18,000 locomotives and 1.2 million cars operating over 113,000 miles of railroads; 20 million recreational boats; 31,000 barges, and over 8,000 U.S. ships, tugs, and other commercial vessels operating on 26,000 miles of waterways, the Great Lakes, and the oceans; and 1.5 million miles of intercity pipelines.
Source: Transportation Statistics Annual Report 1994, U.S. DOT

National Investment in Transportation

Transportation investment and annual expenditures represent a significant element of our overall national assets and expenditures. American households, businesses, and governments spend over $1 trillion to travel 3.8 trillion miles and to ship goods 3.5 trillion miles each year. The net depreciated value of personal motor vehicles alone is $900 billion, and the value of roads and highways is estimated at over $700 billion. When adjusted to formal definitions of the National Income Product Accounts, transportation accounts for 12 percent of gross domestic product. The chart below summarizes the value of current transportation investment, amounts spent on transportation, and transportation-related employment in recent years.

SUMMARY OF CURRENT TRANSPORTATION INVESTMENT				
Transportation Sector	Asset Value ($ billions, 1993)	Annual Investment ($ billions, 1993)	Cost of Services ($ billions, 1992)	Employment (millions, 1992)
Highway/Rail	2,116	359	885	5.1
Air (except ATC)	135	14	90	0.7
Water	41	2	21	0.2
Pipeline (liquid)	21	1	9	0.02
TOTAL	2,313	376	1,005	6.02

Federal Investment in Transportation Research and Development

The federal government has played a major role in supporting innovative transportation technologies in partnership with industry for several reasons, the main one being that the government owns and is responsible for a major part of the infrastructure. The positive impacts of technological innovations in the transportation system can only be measured over a period of several decades. The risks of research investments can thus be very high, and returns on investment so distant that they do not justify private-sector support. This market constraint is exacerbated by the large number and diversity of customers that characterize some modes. Since the public benefits of long-term research often cannot be fully captured by private investors under these circumstances, federal research partnerships are essential for ensuring a continuous flow of innovation.

The federal government also has a unique responsibility for protecting the public's interest in areas like infrastructure renewal, environmental quality,

passenger safety, worker safety, and congestion reduction. The objectives of both business and government can be achieved through well-designed research programs that optimize and leverage the use of both federal and private-sector resources. Often the kinds of long-term research needed to achieve major gains in vehicle efficiency, emissions, or safety are precisely the kinds of research needed by companies to protect their competitive position in domestic and international markets.

Research on aircraft, ships, land vehicles, and other transportation technologies is, of course, also critical for national security. Many defense technology needs can, however, be achieved at much lower cost when defense research is managed in a way that encourages research investment by private firms that can use new technology for both defense and civilian markets. The Department of Defense can no longer afford to support research to sustain firms specializing only in defense markets. Enormous savings can be achieved if defense products can be purchased from healthy and vigorous commercial businesses.

Vision and Goals

The National Science and Technology Council (NSTC) Interagency Coordinating Committee on Transportation Research and Development is charged with ensuring that federal investment in transportation research conducted by all agencies is (1) coordinated to ensure efficient use of federal funds aimed at this mission, (2) focused on projects' identified users, industry, and other stakeholders as being the most critical to achieving success in the agencies' missions, and (3) limited to areas where it is clear that major public benefits can only be achieved through cost-shared federal research. The Committee is composed of representatives from the Departments of Commerce, Defense, Energy, and

Transportation, the Environmental Protection Agency, and the National Aeronautics and Space Administration.

> Investing in technology is investing in America's future; a growing economy with more high-skill, high-wage jobs for American workers; a cleaner environment, where efficiency increases profits and reduces pollution; a stronger, more competitive private sector able to maintain U.S. leadership in critical world markets; an educational system where every student is challenged; and an inspired scientific and technological research community focused on ensuring not just our national security but our very quality of life. *Source: Technology for America's Economic Growth, A New Direction to Build Economic Strength*

The Committee's vision is of a sustainable and seamless intermodal transportation system that effectively ties America together and links it to the world. This system will help citizens and businesses satisfy their needs by providing efficient, safe, secure, and environmentally friendly transportation of people and goods. It will result from a strengthened partnership between government and the private sector focused on effective management and renewal of existing infrastructure, strategic deployment of new technologies and infrastructure, and R&D that supports each of these.

The building blocks for achieving this vision are a sound physical infrastructure; a broad array of technological, design, and behavioral alternatives that provide an overlay of operational information to enable the most effective use of the physical infrastructure; and comprehensive knowledge of the system and its operations. Realizing this vision will require achievement of the following goals:

• A system of personal transportation that meets people's travel needs conveniently and with a minimum of cost and delay. Government and industry will work to achieve the following goals within a decade:

- A prototype of an affordable, attractive automobile capable of up to three times current fuel economy standards and meeting future standards for safety and air pollution.

- A validated technology base that will enable the commercial development of a new generation of safe subsonic and high-speed civil transport aircraft that far surpass today's aircraft in affordability, efficiency, and environmental compatibility, as well as the development of a safer, more efficient, and more productive air traffic management system.

- Demonstrated technologies that will result in bridges and highway surfaces capable of lasting years without frequent or major maintenance.

- Advanced, integrated highway, air, rail, and marine information systems that will monitor system performance and provide operators and passengers with the information they need to maximize their flexibility and choice and that will minimize congestion and environmental impact.

• A system of freight transportation that supports both traditional shipping needs and the new requirements of industries relying on fast, reliable, flexible deliveries. Government and industry will work to achieve the following goals within a decade:

- Prototypes of heavy trucks, rail locomotives, and buses that will minimize the use of nonrenewable resources and will be safe, secure, economically viable, and suitable for use by an increasingly diverse population, and at the same time, be producible and create manufacturing jobs in the United States based on both domestic and export markets.

- A civilian space launch industry capable of competing in any unsubsidized international market.

• A federal procurement system based on life-cycle costing and performance specifications, which gives private firms strong incentives to create and invest in innovations and to meet ambitious safety and environmental goals efficiently and with a minimum of prescriptive regulation.

• A federal government structure that supports wise and effective decisions, policies, and legislation based on private-sector input; comprehensive knowledge of the transportation system's condition, performance and operations; and understanding of the impacts and implications of alternative choices and courses of action.

Guiding Principles

The vision and goals were crafted around the following guiding principles:

• Work with industry and state and local governments in establishing research priorities.

• Ensure sound federal support and effective interagency coordination for key areas of basic and applied research, including engineering topics such as materials and systems analysis.

• Competitive selection of projects should involve independent experts to ensure that choices reflect merit and not politics.

• Significant cost sharing should be provided by industry in all applied research.

• Priority should be given to projects capable of achieving both business successes and meeting social goals such as environmental protection and safety.

• Work within federal R&D budget limits without expectation of new money.

No matter how well designed, federal research investment is only one element of a national strategy aimed at ensuring the continued safety and efficiency of the nation's transportation system. The federal transportation R&D program must also include:

- A business climate that rewards the business investment in R&D must be the principal source of innovation in transportation. This requires minimizing federal deficits so that federal borrowing does not crowd out private investment and trade policies that ensure the widest possible world markets for U.S. transportation products.
- A regulatory system that achieves environmental and other social objectives at the lowest possible cost and with the lowest possible business burden. This means regulations that emphasize performance, not prescription, and administrative measures that minimize red tape.
- A program of lifelong learning ensuring that Americans are equipped to build, operate, maintain, and use tomorrow's sophisticated transportation systems.

The NSTC Transportation R&D Committee's function is to support a balanced national program in these areas.

R&D Priorities and Objectives

The Committee identified R&D needs and priorities by considering transportation systems in terms of four broad categories. The first three categories include the visible elements of our transportation system: the physical infrastructure (roads and bridges, railways, ports and waterways, airports, and launch facilities), the information infrastructure (the sensors, computers, and communications facilities that provide for traffic control and management), and next-generation

transportation vehicles (cars, trucks, buses, trains, ships, and aircraft). The fourth category captures the overall systems-level considerations of transportation system design, planning, management, and operations (assessment of the interactions and relationships among the three physical elements, as well as the performance capabilities and limitations of the people who operate and use the system).

The rate of advance in each of these areas is constrained by many nontechnological factors, but R&D can have a major and often critical impact. Since provision of transportation services and equipment is largely a private-sector activity, industry will generally have an important or even dominant R&D role. However, in many situations federal participation is critical in identifying needs and goals, establishing a knowledge base or concept feasibility, demonstrating and evaluating performance and impacts, and transferring technology to users. Committee subcommittees and working groups have developed the following objectives for coordinated public and private R&D in each of the categories indicated above:

- Physical Infrastructure for Transportation. Develop materials, design methods, nondestructive testing techniques, and other technologies for low-cost, long-lasting highways, bridges, airports, and other structures. Develop low-cost methods for nondestructive testing and repair of existing structures. (Note: This was selected as an NSTC priority area for fiscal year 1996 R&D data collection and review.)
- Information Infrastructure for Transportation: Apply the innovations available from the national information infrastructure to develop an intelligent transportation system that will ensure the safe and efficient intermodal operation of the nation's vehicles and physical infrastructure.
- Next-Generation Transportation Vehicles

- Aeronautics. Maintain world leadership in aircraft, engines, avionics, and air transportation system equipment for a safe, sustainable, global aviation system.

- Space Launch. Ensure reliable and affordable access to space through a stronger U.S. space launch capability that meets the needs of the civilian, national security, and commercial sectors. (Note: Presidential Decision Directive NSTC-4, "National Space Transportation Policy," was issued on August 5, 1994. The Secretaries of Defense, Commerce, and Transportation and the Administrator of the National Aeronautics and Space Administration are preparing a report that will include a common set of requirements and a coordinated technology plan.)

- Personal (Light-Duty) Motor Vehicles. Bring about renewed leadership in automotive technologies through the development of a new generation of energy-efficient, low-emission vehicles that will preserve American jobs and improve American competitiveness. (Note: This was selected as an NSTC priority area for fiscal year 1996 R&D data collection and review. The review was conducted by the Partnership for a New Generation of Vehicles under the NSTC Committee on Civilian Industrial Technology.)

- Medium- and Heavy-Duty Motor Vehicles (Trucks and Buses). Ensure U.S. leadership in truck and bus technology by investing in improved materials, components, and design concepts and other technologies required for improved accessibility, energy efficiency, and environmental characteristics.

- Rail Vehicles (Intercity and Transit). Position the United States as a world technology leader and primary exporter of rail-related equipment and services by facilitating technological innovation in rail vehicle design and construction and by introducing advanced materials and communications

and control technologies that will result in improved performance and reduced costs.

- Ships and Shipbuilding. Restore the competitiveness of the United States in shipbuilding, ship repair, ship design, and ship production in order to ensure a strong and competitive U.S. shipbuilding industry, unsurpassed in building the finest and most technically advanced vessels in the world.

• Transportation System Design, Planning, Management and Operations

- Transportation System Assessment Tools and Knowledge. Develop information required for government and industry managers to make effective decisions about the safe operation of existing transportation systems, as well as new investments.

- Human Performance in the Transportation System. Define appropriate roles for the human-in-the-loop through human-centered automation, and improve the safety and competitiveness of American products through the integration of human performance principles and procedures and the application of new information dissemination, communication, and display technologies to transportation.

Measures Applied in Assessing Priorities

The measures used in identifying priority R&D topics are the key national goals derived from the vision stated above. Priorities also depend upon the potential impact of the research on each measure. Specifically, impact in the areas listed below guided the Committee's efforts. Development of more specific and quantitative metrics in each area will be a focus of Committee activities in 1995.

• Increased Personal Mobility, Access, and Goods Transport. Effective, reliable, low-cost and convenient transportation is central to quality of life and economic health in the United States. Progress is measured in reduced

congestion in urban and intercity travel, reduced costs and delays in intermodal transfer, and a high level of access to employment, goods, and services, particularly for people living in rural areas and for elderly and disabled individuals.

- Economic Growth and Job Creation. Transportation is critical to economic well-being both as an enabler of business activity and in markets for transportation goods and services. This measure includes both direct job creation and competitiveness in transportation-related businesses (e.g., auto and auto parts manufacturing, airlines, and vehicle service companies) and the indirect impact of transportation efficiency on the productivity of the U.S. economy as a whole.

- Enhanced Public Safety and Security. Measures of success include reduced rates of accidents and injuries in the transportation system for both passengers and operating personnel and increased security for freight shipments. A high level of personal safety and physical security is essential for domestic and international travelers, crews and operating personnel, and the general public, and for cargoes being carried.

- Environmental Quality and Energy Efficiency. Transportation produces approximately one-third of greenhouse gases in the United States and is responsible for a major fraction of the pollutants that contribute to urban air pollution. Success can be measured in terms of reduced emissions and progress in areas such as transportation's contribution to noise, spills, hazardous wastes, and other environmental areas. Energy efficiency is closely linked to environmental goals, as well as to transportation costs and national energy independence. Transportation accounts for two-thirds of US petroleum consumption and more than one-quarter of total energy usage.

Policy Context

The purpose of this report is to highlight ongoing federal research efforts in this science and technology field and to identify new and promising areas where there might be gaps in federal support. The report is intended for internal planning purposes within the federal agencies and as a mechanism to convey to the science and technology community the types of research and research priorities being sponsored and considered by federal agencies. The Clinton Administration is committed to a broad range of high-priority investments (including science and technology), as well as to deficit reduction and a smaller, more efficient federal government. These commitments have created a very challenging budget environment—requiring difficult decisions and a well thought out strategy to ensure the best return for the nation's taxpayers. As part of this strategy, this document does not represent the final determinant in an overall Administration budget decision making process. The research programs presented in this report will have to compete for resources against many other high-priority federal programs. If these programs compete successfully, they will be reflected in future Administration budgets.

SUMMARY OF PRIORITY AREAS FOR TRANSPORTATION R&D

The programmatic activities by which these priority research areas are to be addressed vary widely, depending on the nature of the area and the needed R&D, the federal role in each area, and the responsibilities and capabilities of participating agencies. In some cases a single comprehensive and focused program is appropriate; in others, the goals are better achieved through coordination and integration of parallel efforts dealing with different aspects of the subject. Certain broad initiatives addressing particular objectives are represented in more than one priority area. For example, the thrust to advance U.S. aeronautics includes both aircraft technology and a global air traffic control

system, which is also a part of the transportation information infrastructure. Similarly, crash avoidance systems being developed within the intelligent transportation system (ITS) program can be identified with vehicle research as much as for information infrastructure. For each priority area the topics to be addressed, broad objectives and programmatic goals, principal challenges and opportunities, and intended R&D outputs are described below.

PRIORITY AREA: Transportation Physical Infrastructure

Overview

The U.S. transportation infrastructure is a vast network of highways, railroads, waterways, transitways, pipelines, and supporting infrastructures worth some $2.4 trillion. These transportation networks are the physical systems that bring people and products together, the foundation on which our economy and society move. The well-being of this infrastructure is essential to the economic health and vitality of the nation. Maintenance and renewal of our aging and deteriorating infrastructure systems accounts for more than 80 percent of transportation expenditures. Transportation infrastructure systems must be incrementally restored, renewed, preserved, and strengthened, as well as expanded in capacity, if the ever-growing transportation needs of our nation are to be served.

The methods, tools, and materials used in transportation infrastructure construction and maintenance change slowly, limited in part by the need to manage the risks of unexpected weaknesses or problems that may not become apparent for years or decades and by the importance in most decision processes of minimizing initial cost. Another constraint is that the supply industries involved may perceive relatively limited initial markets, with consequent low profits for innovative products. These considerations sharply reduce the private-sector's motivation to perform advanced R&D. The R&D challenge is in part how to address technologies that have such long operating lifetimes and diverse

environments and how to overcome institutional barriers to practical deployment of developed technologies.

However, in other sectors, such as defense and consumer products, various forces have provided a strong incentive for innovation in sophisticated new materials, structural design concepts, and innovative tools and techniques. The inventory of advances potentially worthy of infrastructure use grows day by day, awaiting only the effort to develop specific applications, demonstrations of their effectiveness and long-term viability, and, often, reductions in costs to a competitive level. The reality of this concept is already being demonstrated by results achieved in Europe, where American highway professionals have observed a much more vigorous program for incorporating new materials in foreign roads. The degree to which portions of the nation's highway system are nearing the end of their design life and much transit system infrastructure has already exceeded its nominal life, thereby imposing high maintenance costs and periodic service disruptions, warrants aggressive examination of efficient and practical means of improving materials to renew transportation infrastructure of all types.

Obtaining the best life-cycle performance from the nation's physical infrastructure is important to not only the users, but the taxpayers and the government. Materials used, construction practices, climate, and use of the infrastructure can all vary dramatically, and infrastructure lifetime is normally measured in decades.

APPLICATIONS OF PHYSICAL INFRASTRUCTURE RESEARCH

The approximately 3.5 million miles of surfaced roads in the United States carry one-third of freight ton-miles and nearly 90 percent of passenger-miles traveled. U.S. Department of Transportation (DOT) data show that 10 percent of pavements require immediate repair, and 60 percent call for rehabilitation. One-third of our bridges are structurally deficient. Public expenditures for construction and maintenance of the highway system are approximately $80 billion per year. Obtaining the best life-cycle performance from aging pavements and bridges that have already exceeded their in-service design life is essential to the nation's productivity and mobility.

Defense and consumer sector R&D has produced a rich inventory of high-performance construction materials, structural design concepts, and innovative tools and techniques. These await specific application to transportation infrastructure, demonstration of effectiveness and long-term viability, and often reduction of costs to a competitive level. Examples include composite materials, innovative structural design concepts, advanced corrosion protection and control, structural composites and adhesives, and new pavement mixtures. Extending service life through durable pavements by a marginal 1 percent would save the nation about $20 billion over 20 years.

At the Louetta Overpass on State Highway 249, the U.S. DOT and the State of Texas are working on a high-performance concrete (HPC) bridge that will utilize advanced materials and concrete casting and processing technology. HPC has higher strength and durability for the deck and substructure. Innovative U-shaped beams will be used. HPC is more impermeable to weathering, requiring fewer pillars to support longer spans and a lighter superstructure. Construction and life-cycle cost savings relative to conventional structures and reductions in erection time more than offset the higher initial cost of the materials. The bridge also features advanced nondestructive inspection and testing devices to monitor strain and performance during and after the construction process.

Key Finding

Strategic investment in an infrastructure research, technology, and deployment program is paramount to the preservation and enhancement of the nation's transportation system. There is great potential benefit from R&D directed toward

high-performance construction materials, automated tools and devices, design concepts, and construction methods for renewal of transportation infrastructure.

Major Objectives

Major program objectives in physical infrastructure research and development include the following:

1. Reduce the backlog of needed rehabilitation and renewal of existing transportation infrastructure.
2. Improve the performance of transportation infrastructure, as measured by life-cycle cost, safety, reliability, environmental impacts, transportation service, capacity, and mobility and access for all.
3. Provide the technology base needed for transportation systems of the future, including innovative vehicles and system concepts, intermodal integration, and a sustainable environment.
4. Ensure that the nation's transportation physical infrastructure maintains a high level of performance during seismic and other natural disasters and can recover rapidly from such events.

Challenges and New Opportunities

National leadership is critical in guiding and supporting this area of research. Many existing technical advances are absent or not widely applied in the United States. The following challenges and opportunities are critical to the nation's productivity and economic well-being:

1. National Renewal. There is great potential from research directed toward high-performance construction materials, automated tools and devices, design concepts, and construction methods for renewal of transportation infrastructure.

2. Deployment of Existing Technology and Knowledge. Facilitation of technology deployment is as important as technology generation and is a critical element of R&D in the infrastructure area. Facilities and techniques for accelerated testing can greatly advance the application of performance specifications and life-cycle performance.

3. Preservation of the Environment. Many serious environmental issues arise in infrastructure renewal and maintenance activities. Research is needed to address environmental issues associated with construction and maintenance, such as the use of recycled materials, minimization and removal of waste, and reduction of disruption to the affected area.

4. Reduction of Costs, Improvement of Performance, and Enhancement of Safety. Application of advanced nondestructive inspection and monitoring technologies can yield great benefits in the management of physical infrastructure. These technologies will facilitate development of more efficient maintenance and renewal strategies and priorities and can thereby reduce costs, improve infrastructure performance, and enhance safety.

PRIORITY AREA: Transportation Information Infrastructure

Overview

Economic vitality and growth depends upon reliable, safe, and efficient transportation. The economic burden imposed by congested transportation facilities inhibits job formation and is estimated to cost the nation over $100 billion annually as a result of clogged highway arteries alone. Information systems and technologies play a critical role. The nation's air commerce depends upon advanced air traffic flow control and management systems to alleviate the adverse consequences of air traffic congestion. Information technologies and system management techniques are being pursued to alleviate highway, rail, and vessel

traffic congestion, delay, and inefficiencies, but have yet to be adopted widely in practice. Information technologies also are viewed as a means to ease the paperwork burden associated with shipping documentation, payment transactions, record keeping, and regulatory permits and clearances. It is estimated that motor carriers expend $1 billion to $2 billion annually simply to collect and report vehicle mileage and fuel usage information for tax reporting purposes.

Seamless transportation inherently requires a unique public enabling infrastructure of communication and information technologies, as well as development of comprehensive technology, telecommunications, and information policies and promotion of their application. Information infrastructure R&D leading toward improved transportation safety and efficiency is a priority intricately linked to the national goal of job creation and economic growth.

Overlaying the existing transportation infrastructure with a complementary information infrastructure will dramatically improve transportation service, cost, safety, and efficiency, while lessening adverse environmental impacts. Emerging electronic information systems, navigation, and communication technologies are providing new ways for operators to improve transportation system performance, enabling travelers and shippers to make informed transportation choices. What will emerge is a society infused with information systems that not only connect all modes of transportation into one cohesive system, but also link transportation to the national information infrastructure.

At the core of current federal efforts in this area is the intelligent transportation system program, currently focused primarily on highway applications. This is a public-private partnership to develop and apply a very broad variety of vehicle, roadway, electronics, communications, and information processing technologies and services to improve the efficiency and safety of surface transportation systems. This program will generate a wide array of new products and services, and will contribute to improved mobility and quality of life.

Implementation of a compatible national information infrastructure for transportation in the United States will require the successful integration of a wide range of technologies, including unique public infrastructure. The federal government has an important role to play in this effort. It will be necessary to establish unprecedented levels of cooperation among transportation system users; federal, state, and local governments; research and academic institutions; and private-sector transportation providers. For its part, the federal government provides the national emphasis on safety, congestion relief, mobility enhancement, environmental impact, energy conservation, productivity improvements, and system standards necessary to ensure a nationally compatible and accessible information infrastructure for transportation.

APPLICATION OF INFORMATION INFRASTRUCTURE RESEARCH

Currently, long-haul trucking operates under a series of federal, state, and local regulations that cover such issues as cargo weight, fuel taxes and fuel usage, vehicle safety, driver performance and working hours, and licensing and registration. As a result, trucks can be subjected to numerous inspections and stops during the course of a long-distance journey. This contributes to a reduction in efficiency and an increase in total costs and time required for freight movement.

One possible solution can be found in the Commercial Vehicle Operations (CVO) segment of the intelligent transportation system (ITS) program, which applies advances in electronics, communications, and information technologies to the nation's surface transportation system. A good example of CVO in action is the HELP (Heavy Vehicle Electronic License Plate) program. This is a multistate, multinational research effort to design and test an integrated heavy vehicle monitoring system that combines automatic vehicle identification, automatic vehicle classification, and weigh-in-motion capabilities.

Use of high information containers in intermodal freight movements is now being applied to ensure seamless movement of shipments on to trains, through ports to ships, back to rail and highway vehicles, and on to the final recipient. Conrail is now actively pursuing this technology.

Other facets of ITS now being applied include electronic highway toll and subway fare collection. Electronic toll collection is being used on the New York Thruway at the Tappan Zee Bridge and will soon be applied to other bridges. The Metropolitan Transit Authority is now introducing a transit fare card that will be a "regional passport" for all New York-area transportation, potentially even usable in telephones and taxicabs and at newspaper stands.

Key Finding

Dramatic transportation benefits and generation of markets will result from dynamic and vigorous federal support for the application of communication, information, and navigation technologies to transportation system design, operation, management, and use. While development and use of specific information technologies and capabilities is primarily a private-sector function, the federal government has a substantial interest in public-sector applications, such as

highway infrastructure, transit operations, and air traffic control. The federal government can and should play a critical role in shaping the deployment of compatible and integrated systems.

Major Objectives

Major program objectives in transportation information infrastructure R&D are to:

1. Provide essential or enhanced user services at minimum or reduced federal cost for transportation system operations, and in ways that accelerate the establishment of U.S. industry for hardware, software, and services having a substantial domestic market penetration and strong international market presence.

2. Ensure that the capabilities of satellite-based communication, navigation, and surveillance technologies are developed to the maximum feasible degree, so that their full benefits to transportation and other sectors can be realized.

3. Develop and generate an overall systems-level understanding of the transportation information infrastructure, critical system architecture features, and its relationship to the broader national information infrastructure construct.

Challenges and New Opportunities

The United States benefits from one of the most efficient, effective, safe, and modern transportation system in the world. However, there are a number of areas where improvements could be made that would further enhance ITS benefits. These are captured in the following challenges and opportunities.

- Integrate America's transportation systems. While development and use of specific information technologies and capabilities is primarily a private-sector

function, the federal government has a substantial interest in public-sector applications, such as highway infrastructure, transit operations, and air traffic control. The federal government should play a critical role in shaping the deployment of compatible and integrated systems.

• Enhance the global air transportation system. Continued modernization of communications and navigation systems will play a key role in accommodating air travel growth. Congested airports are undergoing expansion and modernization to meet the ever-increasing level of air traffic. Of particular importance to U.S. airlines and aircraft manufacturers is the internationalization of a worldwide satellite global positioning system (GPS), providing satellite-based communication and navigation. Movement toward such advanced systems will have a significant positive effect on the industry's competitiveness and market potential, as well as open the lucrative market for GPS avionics equipment worldwide.

• Increase productivity and improve customer service. Substantial advances in railroad signal and control system technologies, particularly with respect to rail transit, commuter rail, freight tracking, and shared passenger-freight right-of-way, are possible. Positive train control could enhance safety, and better operational information could improve productivity and customer service.

• Develop "smart" transportation systems. Federal investment in evaluation, development, and deployment of intelligent transportation system applications and technologies, and support for system integration, warrants high priority to identify and reduce impediments and remove disincentives to deployment of these technologies. This will greatly assist in bringing about striking transportation benefits in mobility, safety, efficiency, and productivity.

• Improve logistics. Applications of modern sensing, information processing, display, and communications technologies to traffic and logistics management and other transportation functions on the ground, in the air, and on the sea will have a dramatic impact on transportation and logistics.

PRIORITY AREA: TRANSPORTATION VEHICLES

Transportation system characteristics—performance, safety, security, cost, environmental impact, economic consequences, contribution to quality of life—are largely determined by vehicles that carry people and goods. Vehicles are also a major part of the national economy: the use of private automobiles involves expenditures of over $500 billion annually (more than $160 billion for purchase of new and used cars), and the United States produces $27 billion worth of transport aircraft each year. There is growing concern about the societal impacts of transportation, particularly motor vehicles, on air quality, global warming, and energy use. Major opportunities exist for significant innovation in several areas, as described below.

Aeronautics

Overview

U.S. firms and workers have led the world in the manufacture of aircraft, engines, avionics, and air transportation system equipment. In the process, they have made a major contribution to our nation's security and economy. Aeronautics manufacturing has meant high-technology, high-quality jobs and a positive contribution to our balance of trade. American leadership in aeronautics has also provided global benefits through the economic and cultural exchange and integration made possible through a truly global transportation system.

The growth of this industry, since the infancy of powered flight, has been the result of a strong partnership between the government, industry, and universities. Government investment in aeronautics has been focused on science, technology, infrastructure, and military aviation. This investment, worked in close partnership with industry, provided the conditions for industry success in aeronautics. A government-to-industry technology "pipeline" developed, fueling the rapid advancement of aviation.

Recently, however, the aeronautics industry has begun to face a number of difficult, new challenges. First, the end of the Cold War has permitted a reduction in defense expenditures, including significant cutbacks in development of new aircraft and engines. Second, the weak financial state of the global airline industry has seriously affected orders, backlogs, and deliveries of new civil aircraft. Third, foreign governments have strongly supported the development of their own aeronautics suppliers, challenging U.S. competitiveness in this industry. Although the combination of these factors has had a significant impact on the industry, the United States is still the leader in aeronautics technology and manufacturing. Nationally, we have the infrastructure—government, industry, and universities—to maintain leadership. We must maintain leadership in this global industry if we are to retain the national security and economic benefits that derive from aeronautics. Partnership will once again be the key to meeting national challenges and accomplishing national goals. However, we must now reexamine our traditional partnership in the context of the current and future challenges. Clearly, we must develop an integrated view of aviation system performance and affordability.

APPLICATIONS OF AERONAUTICS RESEARCH

In 1992, the National Research Council identified five areas where R&D can have a major impact in aeronautics.

- Lower cost/greater convenience. Advances in aircraft speed, range, and payload must not increase cost or degrade service. Greater fuel efficiency and reduced operational costs must be vigorously pursued, and increases in airport and air traffic management system capacity must not decrease convenience.
- Greater passenger and cargo capacity. To open markets or expand them, airports and the air traffic management system must be able to serve more people and fly cargo on more and different kinds of aircraft. Safe reductions in aircraft separation, better real-time weather reporting, and facilities for a wide variety of long- and short-range aircraft all increase personal and goods mobility, and thus benefit the industry and the economy.
- Reduced environmental impact. Aircraft environmental impacts limit growth of the industry. Aircraft noise restrictions limit the proximity of major airports to large population centers, the utility of rotorcraft within cities, and the potential for supersonic flight over land. In addition, the impact on the atmosphere of aircraft emissions is an area of growing concern that may, in the near future, limit the number and types of aircraft that fly over the United States and other environmentally conscious countries.
- Greater aviation system safety. The safety of air travel in the United States must be maintained as more planes operate each year. This can be achieved through better understanding of human performance in the cockpit and through improvements in avionics, flight controls, and use of artificial intelligence and fly-by-light/power-by-wire controls, and with improved nondestructive inspection techniques. The safety of air traffic management can be improved still further by more accurate and timely navigation information, such as that provided by the Global Positioning System, through real-time sensing and communication of weather-related information, and through an improved understanding of human performance in the management and control of air traffic.
- Improved aircraft performance. Advances in performance of conventional subsonic aircraft, rotorcraft, short take-off and landing aircraft, and supersonic aircraft will enable more viable expansion into new markets and expansion of existing routes in the United States and throughout the world.

Key Finding

The aeronautics industry represents the strength of American manufacturing. High-technology manufacturing and products support over a million high-quality jobs and thousands of companies. Superior, next-generation U.S. aircraft, engines, avionics, and air transportation system equipment can lead the way to renewed industrial competitiveness for the twenty-first century, supporting an industrial base that is critical to our national economy and security. Maintaining this technological superiority in the face of subsidized international competition, financially weakened global airlines, and reduced defense expenditures will require a strong partnership among government, industry, and academia. The federal government must continue its investment in high-risk technologies with potentially high, but long-term, social and economic benefits. The private sector lacks the resources and incentive to invest in these areas since the benefits of such high-risk investment cannot be realized until far in the future and are difficult for a single firm to fully capture. But the challenges of the current and future markets require that government and industry work together to identify the focus of government-funded cooperative research.

Major Objectives

Major program objectives of aeronautics research are to

1. Maintain the superiority of U.S. aircraft and engines.
2. Achieve an efficient, safe, and affordable global air transportation system.
3. Ensure the long-term environmental compatibility of the aviation system.

Challenges and New Opportunities

It is critical that the US pursue the development of high-payoff component technologies, integration and validation of high-risk technologies, and exploration

of new system concepts and configurations to achieve more revolutionary gains. The following challenges and opportunities are critical to maintaining US competitiveness and improving the affordability of aviation.

• Ensure superiority of U.S. aircraft and engines. A prerequisite for superior aircraft is technological superiority in aeronautics. The United States must continue to develop the product and process technologies required for timely development of superior subsonic and high-speed civil and military aircraft. Pursuit of technologies that support major improvements in aircraft capabilities (including operating cost, capacity, range, fuel efficiency, and safety) can provide a critical edge to maintaining U.S. competitiveness and improving the affordability of aviation. Without investment in these technologies, the United States risks losing the long-term leadership required to maintain a competitive industry.

• Ensure environmental compatibility of aviation. Remarkable strides have been made in reducing the diverse impacts of aircraft on the environment. Noise and harmful emissions have been diminished with the introduction of new and derivative aircraft. Continued research and technology development is required so that more can be done. We must continue research to increase energy efficiency while decreasing noxious and ozone-depleting chemicals. The United States must maintain leadership in these technologies to ensure the environmental compatibility of aviation and long-term competitiveness.

Space Launch

Overview

Space policy is an important topic in the National Science and Technology Council, which incorporated the functions of the National Space Council. The Administration's space transportation policy, as spelled out in Presidential Decision Directive NSTC-4, "National Space Transportation Policy," sets a clear

course for the launch policy part of the nation's space program. It provides a coherent strategy for supporting and strengthening U.S. space launch capability to meet the needs of the civilian, national security, and commercial sectors.

Ideas for improving the nation's space launch systems range from evolving expendable vehicles and shuttle upgrades to single-stage-to-orbit concepts, air-breathing systems, and even more exotic ideas. There is a shortage of federal funds to pursue all promising ideas, however, and budget limits continue to be a painful but very necessary reality if we are to be fiscally responsible.

The U.S. space launch fleet is aging and costly. Major private-sector investments in expendable launch vehicles have helped maintain a U.S. competitive presence in the international market, which has in turn helped hold down launch costs for the U.S. government. Unfortunately, the private sector cannot bear the full burden of improving U.S. space launch systems alone. Growing foreign competition, now including Russia and China, has cut into the market share of U.S. firms, and declining defense budgets have contributed to significant over capacity in traditional expendable launch vehicles. The continuing downsizing and consolidation we have seen in the defense industry has included major space launch manufacturers as well.

Looking ahead, it is expected that government spending for space will remain relatively constant while the commercial space sector demand grows. New commercial opportunities, such as mobile satellite communications, direct audio broadcasts, remote sensing, and satellite-based navigation systems underscore the importance of space to the emerging global information infrastructure. These information-driven industries will be a cornerstone of U.S. competitiveness for decades to come, and dependable, affordable access to space will be crucial to U.S. economic interests. In light of this, commercial requirements will be a necessary and integral part of planning any successful next-generation launch system.

THE FUTURE OF SPACE LAUNCH RESEARCH

In a recent National Aeronautics and Space Administration (NASA) study, six U.S. aerospace firms assessed the benefits that could emerge as a result of lower-cost access to space. Their conclusion is consistent with the Administration's new space transportation policy:

"The future space transportation system selected must be responsive to commercial user requirements in addition to those of government users. While low operating cost is fundamental, other parameters, such as launch dependability, higher reliability, very short booking time, and user friendliness, are of equal importance....Unless the next space transportation system satisfies these needs, that system will not be widely used commercially."

The Administration's policy assigns the chief agencies (NASA and the Department of Defense) a unique lead role, reflecting its particular capabilities and resources. The Department of Defense will be the lead agency for modernizing and evolving current expendable launch vehicle systems. NASA will lead technology development and demonstration of next-generation reusable launch systems, such as the single-stage-to-orbit concept.

Key Finding

Research is needed for the improvement and evolution of the current expendable space launch fleet and development of future reusable space transportation systems with substantially reduced cost.

Major Objectives

Major program objectives of space transportation are:

1. To modernize and evolve our current expendable launch vehicle fleet, taking prudent cost-effective measures to improve performance, reduce costs,

and increase reliability to support national needs. As the lead agency, the Department of Defense will factor in the needs of the commercial space launch industry, with a view towards keeping America competitive in the global launch services market.

2. To push the cutting edge of technology, focusing on the development and demonstration of a next-generation reusable system. As lead agency, the National Aeronautics and Space Administration will work towards a decision in late-1996 on whether to proceed with a subscale flight test to prove the concept of single-stage-to-orbit. The goal of this effort is to support a decision by the end of the decade on the development of an operational next-generation reusable launch system.

Challenges and New Opportunities

1. Reduce costs and improve performance. It is critical that the federal government promote the reduction in the cost of current space transportation systems while improving their reliability, operability, responsiveness, and safety by improving and evolving expendable space launch vehicles and promoting codevelopment with industry of a reusable launch system.

2. Foster competitiveness. Achieving the vision of a more viable, competitive U.S. launch industry will require improvements to infrastructure and to the current launch fleet, and development of new launch systems by the Department of Defense and the National Aeronautics and Space Administration, with support from the private sector. The government will foster the international competitiveness of the U.S. commercial space transportation industry, actively considering commercial needs and factoring them into decisions on improvements in launch facilities and vehicles.

Personal (Light-Duty) Motor Vehicles

Overview

One of the strategic goals of federal transportation R&D is enhancing the overall performance characteristics of vehicles of all types, while expanding the range of alternatives available for meeting transportation needs. Fundamental to achieving this goal is the ability to draw on relevant technology resulting from federal and private-sector R&D activities. If that process can be made effective, the U.S. may maintain and enhance its position as a technical leader and primary exporter of transportation-related equipment and services.

Private automobiles alone account for expenditures of over $500 billion annually in the United States, and for approximately half of U.S. petroleum use. Vehicle-miles traveled continue to increase more rapidly than population, and there are now more cars than licensed drivers in the United States. The functional characteristics of the automobile and widespread private vehicle ownership virtually ensure the automobile's dominant role in transportation for the indefinite future. At the same time, and in spite of continuing improvements, automobiles remain a major cause of degraded urban air quality and a large contributor to atmospheric carbon dioxide, and are involved in most transportation-related deaths and injuries—approximately 40,000 fatalities per year.

The automotive industry directly affects the characteristics of the U.S. transportation system, with consequent profound effects on the domestic economy. About 15 percent of the U.S. workforce is employed in jobs directly or indirectly related to transportation, largely automobiles. Loss of market share of the domestic automotive industry has been a major contributor to the U.S. trade deficit. In 1991, automobile imports cost $54 billion and resulted in a net trade deficit of $41 billion.

Recognizing the importance of the automotive industry to the country's economic well-being, the U.S. government formed a historic new partnership with

the U.S. Council for Automotive Research (USCAR) representing the domestic automakers Chrysler, Ford, and General Motors. The aim of the partnership is to strengthen U.S. competitiveness by developing technologies for a new generation of vehicles. The Partnership for a New Generation of Vehicles (PNGV) was formally announced by President Clinton and Vice President Gore together with the heads of the Big Three U.S. automakers at a White House ceremony on September 29, 1993.

The partnership is intended to provide the scientific foundation, policy, and institutional leadership on advanced vehicle technologies needed to develop affordable, highly efficient, low emission vehicles that will enhance the welfare of the nation by contributing to economic competitiveness, energy security, and improved environmental quality. PNGV supports the federal transportation R&D goals as well. Transportation R&D efforts will be in close coordination with the PNGV.

APPLICATIONS OF PERSONAL MOTOR VEHICLE RESEARCH

Americans' reliance on the automobile has had challenging consequences for the environment—high petroleum consumption, poor air quality, and the possibility of global warming. In the next decade increases in vehicle-miles traveled and in the sheer number of cars will hamper efforts to abate urban air pollution and reduce our reliance on foreign oil. The focus of efforts to reduce these adverse impacts is the development of advanced technologies leading to cleaner, more fuel-efficient cars.

Accordingly, in 1993 the Partnership for a New Generation of Vehicles (PNGV) was announced. PNGV aims to protect the environment and strengthen U.S. competitiveness by developing technologies for vehicles three times more fuel-efficient than today's. In PNGV, government and industry engineering teams will perform research to develop an automobile that is dramatically more efficient, yet safe and affordable. Research efforts will be concentrated in two areas: component technologies to improve fuel efficiency and reduce emissions, and manufacturing technologies that reduce the time and cost associated with design and mass production. This effort will ensure that U.S. automakers lead the world in automotive technology.

Key Finding

The private motor vehicle will remain central to transportation and to many facets of national life for the foreseeable future, with a very large world market. Advanced technologies such as alternative fuels, advanced propulsion systems, improved materials, and manufacturing processes for application to the motor vehicle are necessary to meet environmental and other societal goals. Focused research is also needed to support the development of an infrastructure for alternative transportation fuels and reduced-emission or zero-emission power systems.

Major Objectives

The following are the major program objectives of personal motor vehicle research:

1. Develop a vehicle that will deliver up to three times the fuel efficiency and reduce the emissions of motor vehicles, without compromising other features such as performance, safety, room, and utility.

2. Develop and introduce manufacturing technologies and practices that will reduce the time and cost associated with designing and mass producing this new vehicle.

Challenges and New Opportunities

Achievement of further large improvements in vehicular technologies, as envisioned in PNGV, will necessarily be an extremely challenging undertaking. Given the degree to which the personal automobile is interwoven with American life, it is critical that the implications of alternative choices be clearly understood by individuals, manufacturers, and governments. PNGV is critical, not only in improving the competitiveness of the automotive industry, but also in ensuring commercial readiness of an energy efficient, environmentally friendly new generation of vehicles. Deployment of these vehicles into the population of privately owned automobiles will ensure that the U.S. transportation system continues to offer mobility to an increasing population without restricting personal lifestyles or affecting the environment adversely. Challenges and opportunities for research include the following:

• Advance automotive technologies. It is critical that the U.S. government continue to utilize its base of mission-oriented R&D in generic technology areas that apply to automotive technologies. These include propulsion systems,

materials, system integration, vehicle configurations, alternative fuels, utilization, operations, and fuel distribution and infrastructure.

• Improve productivity. Research is necessary to improve the productivity of the U.S. manufacturing base by significantly advancing U.S. manufacturing technology, including the adoption of agile, flexible manufacturing and the reduction of cost and lead times, while reducing the environmental impact and improving quality.

• Enhance efficiency. Research must be pursued that leads to improvements in the fuel efficiency and emissions of standard vehicle designs. Research should focus on technologies that reduce the demand for energy from the engine and the drive train.

Medium- and Heavy-Duty Motor Vehicles (Trucks and Buses)

Overview

Medium- and heavy-duty trucks and buses represent a significant segment of the transportation sector in the U.S. Trucks and buses constitute 24 percent of the total number of vehicles that travel over U.S. highways and streets, accumulate 29 percent of the vehicle miles associated with road-based vehicles, yet consume 45 percent of the energy used by road vehicles. In addition, trucks and buses contribute heavily to the pollution of our atmosphere and add to the growing concern about the societal impacts of motor vehicles on air quality and global warming. With transportation vehicles representing a major portion of the U.S. economy, it is vital to maintain competitiveness of our U.S.-produced trucks and buses so that the nation can continue, if not increase, our share of the vehicle world market. It is essential that research be directed at reestablishing and improving the position of the United States. as a technological leader and primary exporter of trucks and buses.

APPLICATIONS OF BUS RESEARCH

Diesel engine emissions are a target for improvement in all cities with heavy downtown traffic, but the situation is especially acute in Los Angeles. In order to improve fuel efficiency and reduce emissions from buses, the Federal Transit Administration is sponsoring development of an advanced city bus by the Los Angeles mass transit agency that will be more accessible for disabled passengers, will utilize lightweight materials (for the improvement of fuel efficiency and the reduction of damage to the city streets), and will be powered by an hybrid propulsion system. An efficient, low-floor bus has the potential for increasing sales of buses manufactured in the U.S. in the world marketplace.

The Department of Defense's Advanced Research Project Agency and the Department of Energy are also pursuing bus vehicle improvements, generally with the cost shared by industry, to develop advanced structures, electric propulsion, diesel propulsion, hybrid systems, and enabling technologies. The objective is to enable transportation to take maximum advantage of advanced technologies developed throughout the U.S.

Key Finding

It is prudent that the US government direct R&D efforts toward major improvements in the overall performance characteristics of trucks and buses, particularly related to fuel economy and emission control, and in expanding the range of vehicle alternatives to satisfy local and intercity transportation needs.

Major Objectives

1. Improve and regain the U.S. position in the world truck and bus market.
2. Ensure that advanced truck and bus technologies consider accessibility, energy efficiency, and environmental impacts.

Challenges and New Opportunities

• Improve truck and bus technology for improved performance, safety, energy, and environmental characteristics. Research is needed to develop improved materials, components, and design concepts for transit buses and trucks, including advanced diesel technology, alternative fuels, fuel cells, and electric propulsion. A key challenge for R&D is to reduce truck and bus vehicle emissions sufficiently to meet the Environmental Protection Agency's year 2000 requirements.

• Attract riders to public transportation. Applications of technology innovations to transit buses will offer significant advances in attracting riders, improving service, efficiency, and performance, providing access to disabled users, and reducing environmental impacts. The scale and implications of these improvements in urban transportation warrant high priority for federal R&D.

Rail Vehicles (Intercity and Transit)

Overview

Congestion and delays at major airports, as well as environmental and energy/petroleum consumption issues, have stimulated interest in providing an alternative to the airplane and the motor vehicle for intercity travel in high-travel-density corridors. High-speed rail, and possibly magnetic levitation systems, are perceived to have an important future role in relieving congestion in short-haul intercity corridors. However, questions remain regarding the cost, environmental and other social benefits, breadth of potential applications, and commercial feasibility of high-speed ground transportation systems in the United States. These technologies are a focus of research abroad. Attention has recently turned to the potential value of a high-speed, lightweight, high-power passenger-service locomotive for incremental introduction of improved rail service in corridors that

initially are not likely to generate sufficient traffic to warrant the expense of electrification.

APPLICATION OF RAIL VEHICLE RESEARCH

In heavily traveled corridors in the Northeast, Midwest, Texas, and California, concerns about congestion and pollution have renewed interest in rail transportation as an alternative to air and highway. The Intermodal Surface Transportation Efficiency Act of 1991 authorized a program to determine the efficiency, safety, and economic benefits of high-speed rail for intercity travel. It has the goal of improvements in intercity mobility, with energy, environmental, and economic benefits.

The Departments of Transportation and Energy are participants in this technology program. Goals include: (1) development of a high-speed nonelectric locomotive capable of a sustained speed of 150 mph, to minimize the need for electrification of rail corridors; and (2) the development of a fuel cell powerplant for rail applications.

To achieve the nonelectric locomotive goal, the Department of Transportation has sponsored a program in New York to demonstrate an upgraded turbo-electric train for the New York City to Albany link. The train will be powered by two 1500-hp turbines for sustained speeds of 125 mph. The fuel cell program is to demonstrate that applying these propulsion systems to locomotives can meet railroad requirements for locomotive performance comparable or superior to conventional diesel technology, with dramatically reduced emissions and increased efficiency.

Key Finding

Improved rail vehicle technology will enhance the competitive position of the U.S. in the global marketplace in which many countries rely heavily on their rail

networks and are improving existing railroads or constructing new lines to serve growing economies. Advances in the propulsion and emission performance of passenger train locomotives will substantially increase the range of alternatives available to meet future transportation needs.

Major Objectives

1. Facilitate innovation in rail vehicle design and construction by introducing advanced materials, communications, and control technologies so that performance is improved and costs are reduced.

2. Improve the propulsion and emission performances of intercity and commuter locomotives and expand the range of alternatives available to meet future transportation needs. A specific goal is to develop a fossil-fueled high-speed locomotive or trainset capable of revenue service operations at 150 mph and that meets or exceeds the federal emission standards of year 2010.

3. Position the U.S. as a world technology leader and primary exporter of rail-related equipment and services.

Challenges and New Opportunities

The potential contribution of R&D activities to improvements in safety, cost, sustainability, and personal health associated with intercity rail freight and passenger and rail transit services indicate the value of federal research directed toward achieving the following:

- Improve safety and performance. Development and introduction of advanced materials and structural concepts for high-performance, lightweight vehicles, particularly for commuter rail vehicles, to improve crashworthiness joint service in high-speed corridors, is needed. R&D to accelerate the private

development of advanced train control systems will improve the performance and safety of all rail services.

• Enhance intercity and commuter services. Research to accelerate improvement in the efficiency and performance of nonelectric locomotives used in intercity and commuter rail services is a national need. R&D needs to be conducted to develop alternative prime power sources such as fuel cells, gas turbines, and other hybrid systems for expanded rail services, particularly in high-speed intercity service.

• Increase reliability and reduce expenses. R&D focused on critical components of rail equipment will lead to safer, more reliable, and more efficient service, which will in turn attract more riders and reduce operating expenses per rider. The development of advanced engines with improved emission control devices and alternative fuels will make it possible to satisfy new federal and state emissions standards.

Ships and Shipbuilding

Overview

The National Defense Authorization Act of 1993 required the President to develop "a comprehensive plan to enable and ensure that domestic shipyards can compete effectively in the international shipbuilding market." On October 1, 1993, President Clinton submitted a plan to Congress—a blueprint aimed at revitalizing the U.S. shipbuilding industry. The report states that two steps will have to be taken for U.S. shipyards to compete successfully in the international market. First, subsidies provided by foreign governments to their shipbuilding industries must be ended to ensure a level playing field. Second, U.S. yards must adapt to the demands of the international commercial market. U.S. yards will have to "develop and market competitive designs; fully employ modern technology and manufacturing processes; and remain competitive in wages."

The U.S. shipbuilding industry is unsurpassed in building the finest and most complex naval vessels in the world. With the Cold War ended, these shipyards, like many other defense firms, have been facing a new challenge—translating their skills from the military to the commercial market. Individual shipyards are preparing to meet this challenge.

APPLICATIONS OF SHIP AND SHIPBUILDING RESEARCH

A few short years ago, the American shipbuilding industry was suffering greatly because of declining naval orders and because of subsidized international competition. Thousands of jobs were lost, ruining the economic health of many communities throughout the nation. Additionally, the U.S. lost technological capability in the field crucial to national security. With the advent of President Clinton's policy to build partnerships with the private sector, this situation is being reversed. As a result, the American shipbuilding industry will be able to re-enter the international marketplace and enhance shipbuilding technology.

As part of the Departments of Defense and Transportation MARITECH program, several cooperative agreements have been awarded. One cost-sharing (50 percent-50 percent) agreement, with a total cost of $6.5 million, was awarded to Shipyard Inc., of Mobile, Alabama, to design a double-hulled tank ship. The shipyard plans to use its current facilities, which will permit the construction of vessels of 40,000 deadweight-ton double-hulled product carriers by adapting a proven international commercial design. This type of tank ship will be less likely to damage the environment in the event of an accident, preventing disasters such as the Exxon *Valdez* oil spill. The new designs, production, and processing techniques will permit orders for construction of quality state-of-the-art ships at competitive prices in the international market.

Key Finding

Research and development to improve technology transfer and process changes dealing with manufacturing changes in ship design and production is critical to the nation in terms of competitiveness, security, the environment, and the economy.

Major Objectives

Major program objectives in the ships and shipbuilding technology program include:

1. Develop strong and competitive "world class" international ocean shipping and domestic water transportation industries.
2. Develop a strong and competitive "world class" commercial ship design and production capability.
3. Develop defense-relevant waterborne transportation capabilities to meet peacetime and national emergency needs.
4. Develop a safe and environmentally prudent U.S. waterborne transportation system.
5. Create new jobs in the ship design, ship construction, and ship operating sectors of the maritime industry.

Challenges and New Opportunities

- Increase U.S. competitiveness in ship construction. Ship inspection and construction is a strategically and economically important area in which the nation faces very serious challenges. Technologies involved in inspection, maintenance, repair, disposal, and recycling of ships and other transportation vehicles is a priority.
- Create jobs in shipbuilding. There is an urgent need to lay the technology foundation for the next-generation ships and other vehicles that will minimize the

use of nonrenewable resources and will be safe, secure, economically viable, and suitable for use by an increasingly diverse population, as well as be producible and create manufacturing jobs in the United States based on both domestic and export markets.

PRIORITY AREA: TRANSPORTATION SYSTEM

Design, Planning, Management, and Operations

Transportation touches and is touched by virtually all aspects of modern life, with connections that range from direct to nearly invisible. Our transportation system plays a critical role in meeting key national goals, including individual quality of life, economic vigor, and sustainable development. Transportation is also central to some of the most challenging and contentious public issues we face, such as urban congestion, global warming, public safety, and mandated standards for air quality. It is critical that public and private decisions relating to transportation be based on a solid understanding of the system and its elements, operations, and societal impacts. Two areas are particularly critical in terms of achieving effective transportation investments and safe and efficient system operation: system assessment and human performance.

Transportation System Assessment Tools and Knowledge Base

Overview

A powerful tension exists between our growing technical knowledge and capabilities and our ability to apply those capabilities to meet the legitimate demands of individuals, businesses, and local and national economies. On the one hand, national needs can be satisfied only by energetically pursuing growth and implementation of technology. On the other hand, exploitation of innovative concepts—even the upgrade of conventional systems sufficiently to meet current needs—can fall victim to increasingly rigorous constraints of societal acceptability,

inadequate availability of resources, a focus on immediate rather than distant goals, and difficulties in articulating and developing cohesive and collaborative approaches to large-scale endeavors.

Transportation decisions, whether made in the public or private sector, must address a steadily widening range of considerations, viewed from very long-term perspectives, as well as in terms of immediate concerns: environmental and safety impacts, economic effects for various segments of the population and the economy, national energy and petroleum consumption, land use and living patterns, international agreements, global competitiveness and balance of payments, and appropriate role of each involved party. Each year more and more stakeholders are involved, and the technical realities and uncertainties in each issue become more complex. National goals, embodied in federal legislation, place heavy burdens on state and local agencies for planning and decision making in technically complicated areas. Information and tools for use in meeting these challenges are difficult to obtain or simply do not exist.

An important barrier to achieving this understanding is that the nation's transportation system is a large, highly decentralized and continually evolving complex of vehicles, physical infrastructure, information technology, and support services created and used by individual travelers and shippers, private providers of services and equipment, public agencies, and governments at levels. Technological forces (such as the information and communications revolution), economic shifts (exemplified by globalization), and rising public sensitivity to environmental concerns and long-term sustainability are steadily increasing the rate at which change must be accommodated. While making use of extensive public infrastructure elements, transportation is largely a private-sector undertaking, particularly after the extensive deregulation that occurred during the 1980s—a change still being digested. New technologies, often little understood by decision makers or not fully proven, compete for markets in the transportation

sector. The U.S. transportation enterprise is thus the product of decisions and actions occurring throughout society, driven by many forces, and based largely on near-term economic considerations and balancing of resources, often addressed on a relatively localized basis. With perceived needs often far outstripping available funds, it is difficult to ensure that investment decisions will be based on a time perspective appropriate to the lifetime of transportation infrastructure—typically many decades. In order to improve the ability of all transportation stakeholders to make wise choices, the federal government is moving to providing an enhanced framework of understanding, vision, and guidance to ensure that transportation-related decisions are made, and issues resolved, in a manner fully responsive to the long-term interests of the nation as a whole. Federal stewardship of the overall enterprise can encourage investment decisions and actions by all parties that contribute to seamless, efficient, and effective transportation, while balancing transportation needs against social, economic, environmental, and other goals, both in the present and in a manner that contributes to long-term sustainability.

Some cost and performance measures associated with the nation's transportation system are readily obtained, but many are extremely difficult to capture. Estimation of the consequences of alternative courses of action are shrouded in uncertainty. Identification and quantification of environmental impacts are particularly difficult and contentious undertakings. Examples of the resulting dilemmas include debate over the appropriate role of high-speed passenger rail systems in the United States, development of acceptable strategies for dealing with air quality mandates and urban congestion, and the clash between environmental concerns and the need for transportation infrastructure renewal and expansion. The models and data available to address these issues often provide an inadequate foundation for satisfactory resolution. Further, they are often so complex or data-intensive that their use by local authorities, who have primary

responsibility for many issues, is problematic. Gaps in our understanding of the workings of the national transportation system plague not only governmental agencies and businesses, but also legislative bodies trying to legislate and appropriate productively.

APPLICATIONS OF SYSTEM ASSESSMENT RESEARCH

Almost all of the nation's metropolitan regions face the possibility of having to take steps that inhibit personal mobility—rush hour tolls, parking taxes or limits, alternate driving days, unfamiliar fuels and vehicles. Mayors, county officials, and employers are well aware of the threats. Boston and Atlanta, for example, are both designated as serious nonattainment areas for ozone. Air quality problems are also evident to a public that has become much more sensitive to environment and health issues. However, the best alternatives for solving these problems are not at all clear. The travel planning models in widest use today were developed more than 25 years ago to evaluate major highway corridor alternatives. They were adapted in the 1970s for planning transit services. However, they do not take into account the major changes in suburban travel patterns that have taken place in recent years, or the effects of air pollution and congestion.

The job is too big for any one region to address and has become a critical federal role. It requires teamwork by metropolitan planning organizations, state planners, the Environmental Protection Agency, the Department of Energy, and DOT highway and transit modeling experts. Fortunately, significant advancements have been made in recent years—both in modeling techniques and in computing capacity. The Department of Transportation has recently initiated efforts to make significant improvements in this area, but the challenge is great. The recently established Bureau of Transportation Statistics is actively assessing data needs, performance measures, and effective means of dissemination information. In addition, metropolitan planning organizations in the larger cities have expanded their capabilities to make use of sophisticated modeling tools.

Key Finding

There is an acute need for improved data, analyses, and assessments of all aspects of transportation system performance, including environmental and land-

use impacts, to support policy development and implementation, regulations, legislation, and planning by governments at all levels and the private sector.

Major Objectives

The fundamental program objectives of a transportation system assessment tools and knowledge base program are to:

1. Characterize transportation system usage, future requirements, existing technologies, institutional structure and interactions, relevant domestic/international economic trends, and overall societal impacts.
2. Assess existing and innovative transportation technologies and their potential impact.
3. Assess other technologies of potential importance to transportation systems and operations.
4. Develop and disseminate data concerning transportation system safety, economics, environmental impacts, and other societal concerns.
5. Understand and characterize all types of environmental impacts of transportation, and assess alternative prevention, mitigation, and remediation strategies.
6. Develop focused and broad models for analysis of transportation system operations, functions, and impacts.
7. Assess trade and other industrial impacts of alternative transportation technologies, scenarios, and policies.

Challenges and New Opportunities

Improved understanding of the current transportation system and the needs and behaviors of its users will contribute to better use of existing infrastructure, guide the course of incremental and evolutionary improvements, and support wise

decisions concerning initiatives and associated very large investments directed toward major improvements and innovations. Challenges and new opportunities in system assessment research include:

• Ensure smart american transportation investment decisions: Research is needed for better and more detailed data, analyses and assessments concerning transportation system operational characteristics, performance, condition and environmental and other social impacts, as well as enhanced understanding of transportation-related behavioral sciences and human performance. This information will shape investment decisions, regulatory actions and operational strategies making effective use of advanced technologies.

• Improve system operations and performance: There is a need to address not only specific modes and transportation markets, but also the system as a whole, including interactions and interconnections between modes, and institutional, regulatory and other legal factors that shape and affect the operations and performance of the system.

Human Performance in the Transportation System

Overview

People, acting as designers, operators, crew, or customers/users, are an integral part of transportation systems. Decisions they make, and the performance patterns they exhibit as individuals and as part of organizations, significantly affect the overall productivity and operational safety of transportation systems. Behavioral science provides the methodology to examine systematically the decision-making process and performance capability and reliability. A broadly based, proactive transportation behavioral science research program provides results, data, and methodologies useful to the regulatory and operational requirements of all levels of government. It also supports the operational efficiency

and competitiveness of the private sector in the global transportation community. Of critical importance is the improvement of human performance in transportation systems and the resulting effect on safety, environmental protection, and productivity.

Human error is the principal cause of 60 to 90 percent of transportation accidents. Progress in reducing transportation fatalities, injuries, and property losses is clearly tied to obtaining a better understanding of the root causes of human error and developing appropriate mediating mechanisms that address the individual and how humans function in organizations and with different relationships, training, and motivation.

Successful adoption of advanced technologies requires that people be able to successfully use and interact with new technologies. Technological advances raise new questions about people's ability to understand and operate equipment, while simultaneously coping with increased complexity in system operations. Concern for operator and user needs and capabilities must be included in designs for new technologies to ensure their success. Technological developments will be successful if they can be understood, are user friendly, and can be safely operated. Reduction of transportation fatalities, injuries, and property losses will depend on identifying and removing the causes of human errors or compensating for them. Many research opportunities remain that hold the promise of markedly safer and more productive transportation systems.

APPLICATIONS OF HUMAN PERFORMANCE RESEARCH

The National Transportation Safety Board determined that the probable causes of the grounding of the Exxon *Valdez* were: the failure of the third mate to properly maneuver the vessel because of fatigue and excessive workload; the failure of the master to provide a proper navigation watch because of impairment from alcohol; the failure of Exxon Shipping Company to provide a fit master and a rested and sufficient crew for the *Valdez*; the lack of effective Vessel Traffic Service because of inadequate equipment and manning levels, inadequate personnel training, and deficient management oversight; and the lack of effective pilotage services.

In response to the grounding of the U.S. tank ship Exxon *Valdez*, the U.S. Coast Guard and the Maritime Administration are using human factors research to improve maritime safety. The goal of this work is to find out how the regulatory, guidance, and enforcement activities of the Coast Guard and the industry can improve the safety and competitiveness of maritime operations and to propose specific solutions. Human factors research underway now will provide more effective ways to enhance safety and productivity by:

- Recommending ways to mitigate the negative effect of sleep disruptions on crew members.
- Designating which on-board tasks should and should not be automated.
- Determining how reduced manning levels can impact on-board emergency response capability.
- Designing improved nautical charts, displays, and alarms.
- Improving communication between ship personnel and/or between ship personnel and the Vessel Traffic Service.
- Teaching crew members how to share work tasks and responsibilities more effectively to make better use of crew resources and reduce misunderstandings using bridge resource management skills.
- Using risk assessment techniques to determine the role of human error in the design, construction, reliability, and safety of marine structures.

It is expected that as advanced wide-area navigation technologies, such as Differential Global Positioning System (DGPS), become more widely available they will provide Vessel Traffic Service facilities with real-time information about activity in congested waters not visible on radar. The Coast Guard and the Maritime Administration will need to figure out the safest and most effective ways to design, locate, and operate equipment to display this information to shore stations and mariners. These current and anticipated efforts are part of the Maritime Administration and Coast Guard's integrated plan for safety and human factors work, which is designed to reduce the likelihood of this kind of disaster happening again.

Key Finding

Research in human factors and behavioral sciences is a critical aspect of building the needed transportation knowledge base, improving operational efficiency, and increasing overall productivity. Areas in which better understanding of human performance and behavior is needed include the following:

- Identification and prevention of fatigue and loss of alertness,
- Identification of optimized work-sleep cycles for commercial operators,
- Design of user-friendly working environments,
- Development of strategies for dealing with drug and alcohol use,
- Design of artificial intelligence systems to enable error-free, rapid responses to emergencies,
- Development of methods to test commercial operators for readiness/fitness for operational duty,
- Development of operating procedures that facilitate effective interactions between and among crews and right-of-way controllers, and
- Development of optimized crew resource management schemes.

Major Program Objectives

Major program objectives for research in human performance and behavioral sciences in transportation systems are to:

- Ensure that human performance capabilities and limitations are reflected in transportation system designs and operational timetables and structures.
- Ensure that transportation system designs incorporating new advanced information/communications technologies consider user/customer needs and preferences.

• Foster the development of transportation products and systems that incorporate user interfaces that promote safe, efficient, productive operations and that are user/worker friendly.

• Increase the competitiveness of U.S. transportation products in world markets by making them understandable and easy to use by a wide and diverse population of users/operators.

Challenges and New Opportunities

Cooperation between and among federal agencies responsible for transportation human factors and behavioral sciences research is common. However, fundamental cross-cutting research needs are unmet because of lack of funding support and an existing institutional framework that militates against this type of work. Examples include the following:

• Development of optimized ways of incorporating automation into transportation systems that minimize errors, overcome sensory and cognitive limitations, and improve performance and efficiency.

• Broader application of human performance assessment methodologies across all transportation modes and operations.

• Development of generic human performance measurement tools and data archives that can used for multiple purposes by multiple users.

• Development of analytical models that reflect the effects of individual and group choices and actions/performances on transportation system functioning and efficiency.

• Development of optimization guidelines for the timely and effective aggregation and display of information to system users and operators.

• Development of data bases characterizing the distribution of performance capabilities and limitations, as well as behavior/choice patterns, of the diverse

range of system users/operators that interface with transportation systems now and in the future.

- Defining the type of information customers need, and ways of gathering and presenting it, to make intermodal transportation seamless and readily accessed.
- Development of analytical models of operator performance that can be used as benchmarks for improving individuals' capability to safely and efficiently operate transportation vehicles/equipment.

Accomplishing this work goes beyond the core responsibilities of any single federal, state, or local transportation agency, but holds the potential for:

- Strengthening U.S. competitiveness—by developing optimized systems that account to human capabilities and limitations as they relate to automation in transportation system designs and operations.
- Improving and extending the mobility of Americans—by incorporating practical applications of new information and display technologies. The extent to which U.S. industry makes effective use of modern information technology is central to the competitiveness of transportation-related products and services. There is a need for basic knowledge on human processing, as well as documentation of the differential effects of impairments.
- Fundamental information describing the baseline performance capabilities and limitation of the general population of transportation operators and users, particularly the elderly and the physically challenged, is essential to the design of transportation systems.
- Increasing the safety of the U.S. transportation system—by developing comprehensive analytical models of how vehicle operators function, in terms of sensory, cognitive, and physical characteristics—would derive substantial benefits.

CONCLUSION

The National Science and Technology Council is focused on establishing clear national goals for federal science and technology investments and on ensuring that science, space, and technology policies are developed and implemented to effectively contribute to those national goals. The intensity of this high-level effort to examine R&D across the federal government and to foster a solid working relationship with the private sector is unprecedented. Through this interagency process, overlapping and duplicative research will be avoided and technology policy will be given a higher profile.

Transportation is affected by the activities of many agencies and is largely a private-sector activity. Further, agencies participating commonly emphasized that, even given the importance of the priorities noted, ongoing R&D activities to support specific mission responsibilities is also essential and offers very limited opportunities, at best, for reprogramming. In some cases, formulation of R&D policy and actual priorities must wait upon the shaping of broader federal policies concerning infrastructure investments and the proper allocation of responsibilities among various levels of government and the private sector. As a result, delineation of the appropriate federal R&D role, the part to be played by each agency, and how these are to be coordinated with the private sector and state and local governments is a very complex process. At this point, the goals identified by the Committee are very broad, plans for specific initiatives are not sharply defined, relative priorities have not been set, and budget implications have yet to be identified. In 1995 the Committee will focus on bringing more precise definition to these areas and to establishment of priorities among the many important topics described above.