U.S. Department of Transportation

Research and Development Plan

First Edition
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THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

May 10, 1999

Dear Colleague:

Our Department of Transportation *Strategic Plan* describes "a visionary and vigilant Department of Transportation leading the way to transportation excellence in the 21st Century." The transportation resources we are striving to develop will provide mobility, assure safety for its users, promote economic growth, enhance the human and natural environment, and support national security. A variety of strategies will contribute to making this vision a reality, not the least of which is research, technology development, and then deployment of advanced transportation technologies.

President Clinton has created a unique opportunity to put into place the transportation systems of tomorrow. His "people first" agenda is reflected in new transportation partnerships and enabling research initiatives established in the President's National Science and Technology Council's (NSTC's) *Transportation Science and Technology Strategy* and related efforts. Initiatives like these will lead to a 21st century transportation network that is international in scope, intermodal in form, intelligent in character and inclusive in service. These services will also support American "livable communities" throughout our nation with the best and most effective community, intercity, passenger and freight transportation options and services.

The DOT *Strategic Plan* establishes research and technology as a key "corporate management strategy" which will enable the Department to reach its goals. This *DOT R&D Plan* is a key enabling element of our *Strategic Plan*. The document also fulfills a requirement in the Transportation Equity Act for the 21st Century for an "integrated surface transportation research and technology development strategic plan." It builds on the directions established in the NSTC *Strategy* in setting forth needed partnership initiatives, enabling research, and transportation research and training. Working through related efforts like the Garrett A. Morgan Transportation and Futures Program, which will help the nation develop the transportation workforce of the future, it will help identify the key advances which will transform our transportation services, and help bring those improvements to pass.

Overall, the transportation system of the United States is the best in the world today. To assure our continued prosperity we must create a 21st century transportation system that is efficient and supports economic growth while still being safe, secure and environmentally friendly. We can achieve all of these interrelated goals if we are both visionary and vigilant: visionary about what is possible, and vigilant about seizing the means to realize those possibilities.

Sincerely,

Rodney E. Slater

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U.S. Department of Transportation Research and Development Plan

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List of Acronyms

AAR	Office of Aviation Research
AASHTO	American Association of State Highway Transportation Officials
ACBM	Advanced Cement-based Materials
ADA	Americans with Disabilities Act
ADS-B	Automatic Dependent Surveillance-Broadcast
AEI	Automatic Equipment Identification
AHS	Automated Highway System
APTA	American Public Transit Association
APTS	Advanced Public Transportation Systems
ASOS	Automated Surface Observing System
ATM	Automated Traffic Management
ATTB	Advanced Technology Transit Bus
AVP	Advanced Vehicle Program
AWIPS	Advanced Weather Interactive Processing System
BTS	Bureau of Transportation Statistics
BTU	British Thermal Unit
CEITEC	Construction/Civil Engineering Innovation Technology Evaluation Center
CERF	Civil Engineering Research Foundation
CFIT	Controlled Flight Into Terrain
CHCP	Cargo Handling Cooperative Program
CMM	Capability Maturity Modeling
CRADA	Cooperative Research and Development Agreement
CTAS	Center/Terminal Automation System
CTRD	Committee on Transportation Research and Development
DARPA	Defense Advanced Research Projects Agency
DGPS	Differential Global Positioning System
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOJ	Department Of Justice
DOT	Department of Transportation
DUETS	Demonstration of Universal Electric Subsystems

List of Acronyms (cont.)

EDI	Electronic Data Interchange
EPA	Environmental Protection Agency
EvTEC	Environmental Technology Evaluation Center
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Administration
FHWA	Federal Highway Administration
FMS/RNAV	Flight Management System/ Radionavigation
FRA	Federal Rail administration
FRP	Federal Radionavigation Plan
FTA	Federal Transit Administration
GES	General Estimating System
GIS	Geographical Information System
GPRA	The Government Performance and Results Act
GPS	Global Positioning System
GRMS	Gage Restraint Measurement System
GWEN	Ground Wave Emergency Network
HETS	Heavy Equipment Transportation System
HHS	Department of Health and Human Services
HITEC	Highway Innovative Technology Evaluation Center
HUD	Department of Housing and Urban Development
HZ	Hertz
IDEA	Innovations Deserving Exploratory Analysis
IHSDM	Interactive Highway Safety Design Module
INS	Inertial Navigation System
ICAO	International Civil Aviation Organization
ISTEA	Intermodal Surface Transportation Efficiency Act
IT	Information Technology
ITE	Institute of Traffic Engineering
ITS	Intelligent Transportation System
IVI	Intelligent Vehicle Initiative
KHz	Kilohertz
LTPP	Long Term Pavement Performance

List of Acronyms (cont.)

MARAD	Maritime Administration
MARITECH	Maritime Technology
MDI	Model Deployment Initiatives
MPO	Metropolitan Planning Organizations
MSP	Maritime Security Program
NADS	National Advanced Driving Simulator
NAFTA	North American Free Trade Agreement
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASPAC	National Airspace Performance Analysis Capability
NASSIM	National Airspace System Infrastructure Simulation
NCHRP	National Cooperative Highway Research Program
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Testing
NEXRAD	Next Generation Weather Radar
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Science and Technology
NITI	National Intelligent Transportation Infrastructure
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTBRC	National Transportation Biomedical Research Center
NTDI	National Technology Deployment Initiative
NWS	National Weather Service
OMB	Office of Management and Budget
OREIS	Operation Respond Emergency Information System
OSTP	Office of Science and Technology Policy
PAIR	Partnership for the Advancement of Infrastructure and its Renewal
PAIR-T	Partnership for the Advancement of Infrastructure and its Renewal-Transportation
PNGV	Partnership for a New Generation of Vehicles
PTC	Positive Train Control
PTP	Priority Technologies Program

List of Acronyms (cont.)

R&D	Research and Development
R&D Plan	Department of Transportation Research and Development Plan
RADIUS	Research and Development in the United States
RALES	Research and Locomotive Evaluator/Simulator
RSPA	Research and Special Programs Administration
RTCC	Research and Technology Coordinating Committee
RWIS	Road Weather Information System
S&T Strategy	National Transportation Science and Technology Strategy
SBIR	Small Business Innovative Research
SCADA	Supervisory Control and Data Acquisition
SHRP	Strategic Highway Research Program
SIB	State Infrastructure Bank
SIMMOD	Airport and Airspace Simulation Model
SOCP	Ship Operations Cooperative Program
SOCRATES	Sensor for Optically Characterizing Ring-eddy Atmospheric Turbulence Emanating Sound
TCRP	Transit Research Cooperative Program
TEA 21	Transportation Equity Act for the 21st Century
TRANSIM	Transportation Analysis and Simulation
TRB	Transportation Research Board
TSAR	Transportation Statistics Annual Report
TWG	Technical Working Group
UCRD	Urban Chemical Release Detector
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
UTC	University Transportation Center
VISA	Voluntary Intermodal Sealift Agreement
VMT	Vehicle Miles Traveled
WWW	World Wide Web

process of drafting their own Strategic Plans which describe their missions and long-term goals and how each administration will fulfill them within the overall context of the Department's Strategic Plan.

Addressing a broad range of issues, in November 1997 the National Science and Technology Council (NSTC) Committee on Transportation Research and Development (CTRD) released the Transportation Science and Technology Strategy (S&T Strategy). This was the first time that the Federal government has provided a common basis for the direction of transportation R&D priorities and coordinated research across agency lines. A major aspect of the S&T Strategy is the identification of major strategic partnership, enabling research and education and training initiatives that could be pursued in public-private partnerships involving Federal agencies, state and local governments, the private sector, and the academic and research communities. Joining the Department of Transportation in this endeavor were the other Federal agencies with significant transportation missions and/or R&D activities and interests: the Departments of Commerce, Defense and Energy; the Environmental Protection Agency; the National Aeronautics and Space Administration; and the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB).

Research and technology is one of the most significant cross-cutting topics within the Department of Transportation, and the Department's R&D efforts both influence and contribute to the activities of other major Federal agencies, as well as other levels of government, the private sector, and the academic and research community. This document, the Department of Transportation Research and Development Plan (R&D Plan), has been prepared in keeping with the guidance and direction reflected by these and related policy and planning documents to bring greater consistency and cohesion to the Department's separate R&D programs and to address transportation system-level performance through better coordinated and integrated R&D.

This R&D Plan has six major sections. Chapter I provides a brief description of the key elements of the national transportation system, as well as the challenges and opportunities that confront us when making technological improvements to it. Chapter II describes the close relationship between the Department's strategic goals and those outlined by the NSTC in the S&T Strategy, as reflected in transportation R&D. Chapter III shows in detail the cooperative nature of these R&D activities, by relating the NSTC's new transportation partnership initiatives to the existing DOT R&D partnerships and technology transfer programs that fall within the context of these initiatives. Chapter IV presents the DOT near-term and long-term enabling research programs in the context of the six enabling research areas recently defined by the NSTC. Chapter V describes the process by which measures of success for DOT R&D programs are being developed. Finally, Chapter VI discusses several key issues that impact the implementation of the results of these R&D activities in the transportation system, as well as important incentives that are available to assist in this process.

Introduction and Purpose

Since the foundation of the U.S. Department of Transportation (DOT) in 1967, the various modal administrations have managed their own research and development (R&D) programs, responding to the particular needs of their own constituencies both within and outside of the Department. This situation has had the benefit of keeping the direction of these activities focused more specifically on the needs of the immediate users of their products. Unfortunately, it also makes it difficult to coordinate similar projects and share the benefits of these programs more widely across the Department, as well as across the federal government itself. It has also meant that the planning for these programs has not always consistently taken account of wider factors, such as the cross-modal opportunities created by promising information, telecommunications, and other technological advances.

In response to these concerns, the Department of Transportation has taken several important steps in recent years to provide a common framework within which its R&D programs can be planned and managed more efficiently and effectively. Various committees and councils involving the Department's R&D offices have been meeting since at least the 1980s to share information about modal research activities. Then, the Intermodal Surface Transportation Efficiency Act (ISTEA) legislation of 1991 required that the Department prepare an annual report to Congress on its surface transportation R&D activities and plans. As a result, four editions of the Surface Transportation Research and Development Plan have been submitted to Congress. Each version includes information on the relevant surface transportation R&D programs of each modal administration, including comments on U.S. Coast Guard (USCG) and Federal Aviation Administration (FAA) projects with an application to surface modes.

In addition, the Federal Aviation Administration regularly publishes several planning documents related to aviation R&D and technology applications. Among the most notable of these are the FAA Research, Engineering and Development (RE&D) Plan and the Aviation System Capital Investment Plan. These plans focus primarily on the impact of Department of Transportation surface and aviation R&D activities on its own programs as well as the commercial transportation system; they do not specifically address the national security implications of these same activities.

On September 30, 1997, Secretary Slater released the U.S. Department of Transportation Strategic Plan 1997-2002 (Strategic Plan). This document presents a common vision, mission statement and five major strategic goals for all elements of the Department to pursue over the coming five years. It is already being used extensively across the Department for direction in planning, budgeting and program management. Research and technology activities are a significant aspect of this document and represent one of the six specific Department-wide 'Management Strategies' described in the Strategic Plan. In addition, the Department's modal administrations are in the

Chapter I: The National Transportation System

A. Status

The transportation system in the United States is made up of interconnected infrastructures including highways, transit systems, railroads, airports, waterways, pipelines, and ports, as well as the vehicles, aircraft and vessels that operate along them. It also includes the industries that manufacture and service vehicles and construct facilities, organizations that administer transportation programs, and companies that provide transportation services. The transportation infrastructure has multiple owners and operators from federal, state and local governments as well as private industry.

The transportation system has many sectors, often termed "modes." They include highways, mass transit, rail, aviation, waterborne, and pipelines. Passengers and freight are moved using one or more modes and modal transfers between the origin and destination. The need to move passengers and freight domestically and internationally in an efficient and effective manner has increased the interdependencies of the different modes and competing companies in the marketplace.

Each of the elements of the transportation system has a unique set of relationships between the public and private sectors. (*See Figure I-1*) The growth of the railroad industry, for example, was primarily driven by private investors and companies, with some encouragement from the government. The National Airspace System (NAS), on the other hand, is operated by a federal agency, the Federal Aviation Administration (FAA), even though most of the aircraft that fly within it are owned and operated by private individuals or companies. Highways, in contrast, are often funded by governmental agencies, even though the government plays only a limited role in managing the actual daily flow of traffic. Thus, both public and private sector entities share responsibility for most of the transportation system. The introduction of new technologies in all sectors in attempts to improve the performance, efficiency, and safety of each mode, as well as that of the overall transportation system, needs to recognize this shared responsibility.

Over time, the public and private sectors of the United States have invested heavily in expanding the efficiency and effectiveness of the transportation system, and both economic and non-economic benefits have accrued. Major economic centers have been connected by a variety of transportation options, using one or a combination of modes. Economic development has thereby been accelerated; the mobility of U.S. citizens has been enhanced; and key national security goals have been attained.

Over the last decade, new technologies and transportation logistics practices have emerged as important driving forces for the system's evolution; changing the face of transportation along with many other aspects of daily life. Like many other sectors of the U.S. economy, transportation is changing in response to the demand for improved and more reliable service that currently characterize strategic business thinking.

Global economics and the need for international competitiveness are pushing industries to respond more efficiently to the demands of the marketplace. A nation's transportation system needs to provide maximum access to the broadest range of markets and sources at the lowest possible cost. In response to these pressures, new products, production techniques and markets are continually emerging. For example, inventory buffers of key components that factories used to keep on site to assure adequate supplies are being radically reduced by 'just-in-time' shipment practices, saving both time and money.[1] In addition, competitive pressures and the introduction of new technologies have reduced the redundancies in the overall transportation system as under-utilized or poorly performing elements are abandoned or eliminated.

Thus, the U.S. transportation system "is evolving dramatically: it is moving

Figure I-1

The Transportation System in Summary: 1995

Highways & Crash Statistics

- 3,900,000 miles of public roads
- 205 million commercial and private vehicles
- 4 trillion passenger-miles
- 920 billion ton-miles of freight
- 18,000 trillion BTUs consumed
- 41,798 fatalities & 3.4 million injuries

Mass Transit

- 508 transit providers
- 120,000 vehicles
- 41 billion passenger-miles
- 120 trillion BTUs consumed

Railroads

- 150,000 route miles of track
- 20,000 locomotives, 1.2 million freight cars, 6,500 passenger cars
- 6 billion passenger-miles (Amtrak)
- 1,300 billion ton-miles of freight
- 500 trillion BTUs consumed

Aviation

- 5,500 public-use airports
- 175,000 commercial and private aircraft
- 403 billion passenger-miles (domestic)
- 13 billion ton-miles of freight (domestic)
- 1,800 trillion BTUs consumed

Water

- 25,000 miles of navigable waterways
- 12 million commercial and private vessels
- 800 billion ton-miles of freight (domestic)
- 1,350 trillion BTUs consumed

Pipelines

- 1.6 million miles of pipelines
- 600 billion ton-miles of oil and 19 trillion cubic feet of gas transported
- 700 trillion BTUs consumed

Source: U.S.DOT, BTS, *Transportation Statistics Annual Report 1996, (TSAR 1996)* pp. 4-5; *NTS 1997, passim.*

[1] *Transportation Statistics Annual Report (TSAR) 1995*, U.S. Department of Transportation, Bureau of Transportation Statistics, pp. 116-117.

from one serving a material-intensive industrial production system based on economies of scale, to one serving an emerging flexible, knowledge-intensive production system with agile firms exploiting economies of scope."[2] As the industry makes this transition to incorporate more information technology into its systems, it will remain of fundamental importance to the U.S. economy.

B. Challenges and Opportunities

Given the variety of conditions, uses, and institutional environments within it, maintaining and enhancing the national transportation system poses a dynamic, multi-dimensional challenge. There are complex issues that cover such diverse topics as congestion, technological obsolescence, environmental concerns, harmonization of regional and international standards and practices, and work force education and training. Not surprisingly, service providers in each mode are seeking solutions to these common challenges by the application of promising technological opportunities to their operations.

Surface Transportation

The Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) regularly produce reports on the condition and performance of the nation's highways and transit systems. According to the latest information for 1996, about 37% of urban Interstate miles and 23% of rural Interstate miles were in only poor or mediocre condition, while about 35% of urban highway bridges and 24% of rural highway bridges were judged to be either structurally or functionally deficient. The average condition of the nation's transit vehicle fleet stayed about the same for the past ten years, with a slight worsening of the average condition of medium and larger buses and commuter railcars. Meanwhile, , congestion was increasing, especially in major urban areas. Congestion brings associated travel delays and increases in both pollution and fuel usage, which leads to inefficiencies in both passenger and freight movements. These consequences in turn spur demands for the construction of additional capacity, or for improvements to the management of existing transportation sectors.[3]

Expanding the physical infrastructure and improving its quality can have a positive impact on transportation productivity by allowing for higher average speeds of travel and reducing congestion. In the past few years, however, traffic volume has grown five to six times faster than the mileage of major arterial highways. (*See Figure I-2)* Urban highway construction is occurring at only one-half of the pace necessary to stay abreast

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2 *Ibid*, p. 117.

3 *TSAR 1995,* pp. 22-23, and *TSAR 1998*, pp. 33-35.

Figure I-2

Use of the Highway System: 1980 and 1991

	1980	1991	% change
Total Interstate miles	41,216	45,280	9.9%
Total Major Arterial miles	174,999	191,072	9.2%
VMT (Millions), Interstates	293,060	490,336	67.2%
VMT (Millions), Major Arterials	744,838	1,134,990	52.4%

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics Annual Report 1995*, (Washington, DC: 1995), pp. 124-125.

of the growth in traffic. Additional construction, however, can be limited by right-of-way restrictions and local opposition.

Thus, solutions to growing congestion are increasingly being sought from technological improvements which assist in planning, management and operations. The most important of these is the Intelligent Transportation Systems (ITS) program. ITS represents the application of advanced communications, navigation, sensor and information systems technologies to improve the performance of transportation systems. In the past five years, the federal government alone has invested about $1 billion in ITS research and operational tests, with significant additional funding and efforts from the private sector, and from state and local governments. The ITS program, in fact, is the single largest Department of Transportation research program in the current decade.

In a similar process, the nation's railroads – freight, intercity, passenger, and commuter – are developing and testing more sophisticated tracking and train control systems to enhance both safety and efficiency. Current automatic block and centralized traffic control signal systems are very reliable; but it is still possible for individuals to make mistakes that cause collisions or overspeed accidents.

New Positive Train Control (PTC) systems are made up of the same technologies used in ITS: digital data links connecting locomotives, maintenance-of-way equipment, wayside base radios, and control centers; on-board computers, positioning systems, data radios, and display screens on locomotives and maintenance-of-way equipment; and control center computers. PTC systems can reduce the probability of collisions and overspeed accidents by two orders of magnitude, and can also improve running time, service reliability, capacity, and rolling stock and crew utilization.

Railroads have also installed another ITS technology, automatic equipment identification tags, on all cars and locomotives. This permits scanners placed along the track to trace shipments accurately. When trucks and containers are equipped with similar tags, the efficiency of the intermodal freight system will be enhanced.

Aviation

Current forecasts indicate that the aviation industry will continue to expand. Air travel is now an integral part of both business and personal travel. In fact, flying has increasingly become the preferred means of long-distance travel, particularly for those on business or with tight schedules. The development of an integrated global economy with rapidly expanding international commerce and tourism has further added to the mounting demand for airline travel.

However, commercial aviation growth may be limited over time by rising fuel and operating costs, as well as the increasing congestion at the busiest airports. Building new airports and enlarging existing ones is especially difficult. The growth of urbanized areas leaves less available space near city centers. Public pressure to reduce current aircraft noise levels, as well as environmental concerns over losing wetlands and other habitat areas, all inhibit airport expansion and construction. In the past twenty years only one brand-new major airport has been built in the U.S.

Given these constraints, the FAA and the airline industry have turned to improvements in operating technologies, particularly in communications, to help increase the capacity of the commercial aviation system. The most significant of these interconnected technological initiatives include: the modernization of the National Airspace System (NAS), a move to "free flight" of en-route aircraft, the introduction of Global Positioning System (GPS) satellite-based navigation, digital data links between aircraft and the ground, and improved weather forecasting tools.

These new capabilities will allow much more flexibility to be engineered into the system. The recent report of the President's Commission on Aviation Safety and Security summarized these dramatic developments as follows:

> "Information technology presents opportunities that will again revolutionize the industry, in ways as significant as the introduction of the jet engine forty years ago. Air traffic today is still controlled through ground-based radar, and on a point-to-point basis. Satellite-based navigation will bring a fundamental change in the way that air traffic is directed, and may make the notion of 'highway lanes in the sky' as obsolete as the bonfires that used to guide early fliers. Digital technology will replace analog systems, making communications with and among aircraft dramatically faster, more efficient, and effective. These and other new technologies offer tremendous opportunities for improved safety, security and efficiency, and

will transform aviation in the same way that the Internet and World Wide Web are transforming the way the world does business."[4]

But improved technologies and changes in aviation also bring new information and communications security concerns. Increasing reliance on GPS and digital data links, for example, means that losses of its navigational capabilities could create major disruptions in both the flight of individual aircraft and the operation of the overall air traffic network.

The introduction of increasingly sophisticated communications technology, with its related concerns, applies to more than just the aviation industry. The interconnectivity of telecommunications systems cuts across the modes. In an increasingly technological world, the security of complex information and communications systems becomes critical. Both the efficiencies and the vulnerabilities of the new technologies affect all of the transportation modes.

In an aviation context, consolidating separate aspects of the system into fewer but more efficient components may also make the consequences of losing one of these components more severe than at present. Additionally, the roles and functions of such key personnel as air traffic controllers and pilots may well be changing. Pilots will likely assume more responsibilities for making decisions about their own aircraft's direction, while controllers may do less "controlling" and more "monitoring" of the nation's airspace. One result will be a need for increased research into human factors and new management techniques, so that the advantages of these new technologies can be most effectively applied, not only to the aviation system, but to any transportation field where computer technology and telecommunication capabilities redefine the human involvement. Finally, improving access to airports via better highway and transit connections can also help to provide better service to passengers.

Maritime, Pipeline, and System Integration Technologies

Other technological trends are apparent across the transportation system. The efficient and cost-effective movement of freight requires a virtually seamless process of container movements from one mode to another – particularly between ships and the trucks or rail cars that will move the containers inland – which in turn depends on a harmonious merging of these various physical infrastructures. Automation technologies are increasingly being used to help manage and track this process. Examples of this trend include: transmitting shipping documents by Electronic Data Interchange (EDI) and tracking cargo by automatic equipment identification (AEI) systems; the explosive growth of business use of the Internet to offer customers an inside look into the real-time processing of their orders; and the use of automated Supervisory Control and Data

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[4] *Report of the White House Commission on Aviation Safety and Security,* February 12, 1997, p. 1

Acquisition (SCADA) systems by pipeline companies to expedite movements of oil and natural gas over thousands of miles of pipeline.

C. Summary

As can be readily seen, transportation is undergoing a continual dynamic process of responding to the needs and requirements of its users by trying to provide more efficient and effective services. In the process of improving operations, however, a common constraint has arisen in nearly every case: the increasing difficulty of physically expanding the existing infrastructure. Environmental concerns, and competing demands for the use of scarce urban land are among the major obstacles to this approach. The opening of a new major airport is a rare occurrence; the construction of new Interstate highways is virtually complete; and even port and harbor dredging operations have been considerably slowed.

In this context, it is not surprising that transportation service providers across the modes have reached similar conclusions about the best prospects for making these improvements: the application of technological advances. In particular, telecommunications and information systems are being intensively studied and applied to improve operations in all modes.

In light of these common problems, and the turn to technological applications as the best solution, much will be gained by assuring that the Department's separate R&D programs occur within a common framework of goals and guidance, and that their results are as widely disseminated as possible. It is equally important that these activities be carefully coordinated with the needs of transportation users, as well as with the research efforts of others engaged in this common endeavor.

Chapter II: Strategic Goals and Transportation R&D

A. The Department of Transportation Strategic Plan

On September 30, 1997, Secretary of Transportation Rodney Slater announced the publication of the United States Department of Transportation Strategic Plan for fiscal years 1997 through 2002. This Plan is the result of reflection upon the statutory and policy directions under which the Department operates, as well as thorough consultations with transportation stakeholders in the public and private sectors. It provides a public statement of the vision, mission, and the strategic goals of the Department and the path it will take in pursuing these objectives over the coming five years.

The Department's *Vision Statement* is to be:

> "a visionary and vigilant Department of Transportation leading the way to transportation excellence in the 21st Century."[1]

The accompanying *Mission Statement* is that the Department will

> "serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future."[2]

In pursuing this *Vision* and performing its *Mission*, the Department will also seek to accomplish five *strategic goals* that are key to this process (*See Figure II-1).* These five strategic goals are related to: (1) the *safety* of the national transportation system; (2) the *mobility* afforded by this system; (3) the contribution of transportation to *economic growth and trade*; (4) the impact of transportation activities on the *human and natural environment*; and (5) the extent to which transportation supports important *national security* requirements.

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1 U.S. DOT, *Strategic Plan, 1997-2002*, September 30, 1997, p. 7.

2 *Ibid.*

Figure II-1

DOT STRATEGIC PLAN: STRATEGIC GOALS

1. **Safety** -- "Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries and property damage."

2. **Mobility** -- "Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offers flexibility of choices."

3. **Economic Growth and Trade** -- "Advance America's economic growth and competitiveness domestically and internationally through efficient and flexible transportation."

4. **Human and Natural Environment** -- "Protect and enhance communities and the natural environment affected by transportation."

5. **National Security** -- "Advance the nation's vital security interests in support of national strategies such as the National Security Strategy and the National Drug Control Strategy by ensuring that the transportation system is secure and available for defense mobility and that our borders are safe from illegal intrusions."[3]

Each of these five strategic goals also has: (1) a set of accompanying "outcome goals"; (2) a series of specific steps that the Department will take in its efforts to attain these strategic goals; and (3) a collection of specific "indicators' by which progress towards attaining these goals can be measured. These items are shown in the following charts *(See Figures II-2 through II-6).* [4]

[3] *Ibid.*

[4] Some of the specific goals and indicators in these charts may be changed in the near future to reflect the latest versions of the Department's annual *Performance Plans.*

Figure II-2

DOT Strategic Goal #1 – "Safety"

DOT Outcome Goals:

1. Reduce the number of transportation-related deaths.
2. Reduce the number and severity of transportation-related injuries.
3. Reduce the rate of transportation-related fatalities per passenger-mile-traveled and per ton-mile of total freight shipped (or vehicle miles traveled).
4. Reduce the rate and severity of transportation-related injuries per passenger-mile-traveled and per ton-mile (or vehicle miles traveled).
5. Reduce the dollar loss from high-consequence, reportable transportation incidents.
6. Reduce the number of reportable transportation incidents and their related economic costs.

How DOT Will Achieve the Strategic Goal:

1. Emphasize research in injury biomechanics, human performance and behavior, and lifetime driver learning to maximize safety opportunities in crashworthiness, crash prevention, and crash avoidance areas.
2. Promote public-private partnerships to demonstrate cost-effective safety technologies, such as intelligent vehicles, air traffic management, and enhanced weather services.
3. Develop, deploy and promote cost-effective information technology (IT).
4. Advance transportation research exploring causes of, and countermeasures for, transportation incidents in all modes of transportation.

Representative Indicators:

1. The number of highway-related fatalities and injuries per 100 million vehicle miles traveled (VMT).
2. The number of fatal aviation accidents per 100,000 departures.
3. Percentage of mariners reported in life-threatening danger that are rescued.
4. The number of rail-related crashes per million train-miles.
5. The number of transit-related fatalities and injuries per 100 million transit passenger miles traveled.
6. The number of gas transmission and hazardous liquid pipeline failures.
7. The number of serious reportable hazardous materials transportation incidents.

Figure II-3

DOT Strategic Goal #2 - "Mobility"

DOT Outcome Goals:

1. Improve the structural integrity of the transportation system.
2. Balance new physical capacity with the operational efficiency of the nation's transportation infrastructure.
3. Increase intermodal physical, information, and service connectivity.
4. Increase access to the transportation system for the movement of all people and freight.
5. Provide preventive measures and expeditious response to natural and man made disasters in partnership with other agencies to ensure that we provide for the rapid recovery of the transportation system.

How DOT Will Achieve the Strategic Goal:

1. Deploy, in partnership with industry, new and emerging IT applications that improve the quality and efficiency of the nation's transportation system (e.g., enhanced navigational guidance systems, automated control systems, smart highways).
2. Improve technical assistance.
3. Promote public-private partnerships to demonstrate innovative technologies that improve infrastructure and operational efficiencies, such as the Intelligent Transportation Systems (ITS), the Global Positioning System (GPS), the Internet, and new materials and designs.

Representative Indicators:

1. Percentage of kilometers on the National Highway System (NHS) that meet International Roughness Index pavement performance standard of less than or equal to 2.68 meters/kilometer.
2. Number of available commercial aviation landing approaches using Global Positioning System (GPS) technology.
3. Percentage of total operating days that marine aids to navigation are available for use.
4. Amtrak customer satisfaction index.
5. Average age in years of transit vehicle fleets.
6. Percentage of transit facilities in compliance with the Americans with Disabilities Act (ADA).

Figure II-4

DOT Strategic Goal #3 - Economic Growth and Trade

DOT Outcome Goals:

1. Reduce the real economic cost of transportation, taking into account changes in the efficiency and quality of transportation services.
2. Reduce the average time for delivery of people, goods and services to their destinations.
3. Improve the reliability of the delivery of people, goods and services to their destinations.
4. Increase the education and public awareness of individuals in transportation-related fields.

How DOT Will Achieve the Strategic Goal:

1. Assess the performance of the transportation system as a whole.
2. Work with partners in transportation-related industries and other branches of government to facilitate technology development and supporting and harmonizing international standards.
3. Investigate and foster best IT practices and trends through partnerships with industry and other Federal, state, and international entities.
4. Apply advanced industrial design, environmentally-friendly technology and manufacturing techniques in transportation-related industries to cut costs and improve product marketability.
5. Promote private-public partnerships that demonstrate more efficient movement of people and freight, such as the movement of freight through a major international port.

Representative Indicators:

1. Hours of delay per 1,000 VMT on federal-Aid highways.
2. Percentage of commercial flight operations arriving on time.
3. Gross tons of commercial vessels under construction in U.S. shipyards.
4. Number of Amtrak trips along the Northeast Corridor (Boston to New York).
5. Total transit revenue vehicle hours of service.

Figure II-5

DOT Strategic Goal #4 - "Human and Natural Environment"

DOT Outcome Goals:

1. Reduce the amount of transportation-related pollutants and greenhouse gases released into the environment.
2. Improve the natural environment and communities affected by DOT-owned facilities and equipment.
3. Reduce the adverse effects of siting, construction and operation of transportation facilities on the natural environment and communities, particularly disadvantaged communities.

How DOT Will Achieve the Strategic Goal:

1. Investigate technological and behavioral implications of alternative transportation systems to determine those that minimize impacts on long-term environmental sustainability.
2. Promote public-private partnerships to demonstrate new environmentally friendly technologies such as alternate fuels and infrastructure for the next generation of vehicles.
3. Use virtual *versus* physical transportation mechanisms to mitigate harm to the environment.

Representative Indicators:

1. Total mobile source emissions in short tons.
2. Number of residents exposed to significant aircraft noise (65 decibels or greater).
3. Gallons of oil spilled into the water by marine sources per million gallons shipped.
4. Average quantity of liquid hazardous materials released by all modes into the environment per serious transportation incident.

Figure II-6

DOT Strategic Goal #5 - National Security

DOT Outcome Goals:

1. Reduce the vulnerability and consequences of intentional harm to the transportation system and its users.
2. Ensure transportation physical and information infrastructure and technology are adequate to facilitate military logistics during mobility, training exercises, and mobilization.
3. Reduce the flow of illegal drugs and illegal aliens entering the United States.

How DOT Will Achieve the Strategic Goal:

1. Develop and maintain partnerships with other federal agencies, state/local governments, law enforcement, transportation industry and foreign governments, working cooperatively to identify the vulnerabilities of our national transportation system and jointly develop and implement countermeasures, harmonize our respective short term and long term goals, and maintain a close daily working relationship.
2. Conduct research to better detect and deter threats to the transportation system.
3. Ensure that the information systems that support transportation systems are secure from unauthorized access and destruction.
4. Develop and share security related information and cooperate to implement strong security procedures and technology in the U.S. and internationally.

Representative Indicators:

1. Index of Department of Defense satisfaction with defense mobility planning exercises.
2. Detection rate of simulated explosive devices and weapons at airports.
3. Square feet of sealift capacity of ships enrolled in the Maritime Security Program (MSP) and Voluntary Intermodal Sealift Agreement (VISA).
4. Reduce illegal drug smuggler and undocumented migrant success rates in maritime routes.

The Department's research and technology activities are developed to serve as a *Research and Technology Management Strategy* supporting the overall goals of the *Strategic Plan*.[5] The goal of this management strategy is to:

> "Advance transportation research and technology to shape a fast, safe, efficient, accessible and convenient transportation system for the 21st Century through strategic planning, world-class research, better exchange of information on useful technological innovations, partnerships, research and education."[6]

The other five management strategies are in the areas of: ONE DOT, Human Resources, Customer Service, Information Technology, and Resource and Business Process. ONE DOT, in particular, refers to the goal of enabling the Department to integrate the needs and viewpoints of all of the transportation modes in its activities.

The Department's research and technology activities provide an essential means by which it can attain its mission and fulfill the five strategic goals. It is through these programs, and the application of the technological advances that result, that the nation's transportation system can be most effectively improved. These R&D activities support the following three major categories: operational missions, regulatory functions, or national needs.

R&D to Support Operational DOT Missions. Much of the Department's R&D is in support of DOT programs responsive to specific operational functions embodied in legislation and agency mandates. For example, a substantial portion of the FAA R&D budget is associated with evolution and renewal of the nation's air traffic control. Research also provides a necessary foundation for the wide spectrum of services provided by the U.S. Coast Guard.

R&D to Support DOT Regulatory Functions. Many other DOT responsibilities, primarily concerned with safety, involve development and promulgation of regulations, standards and specifications. NHTSA's motor vehicle regulatory process, for example, requires research to understand accident causes, identify and assess alternative approaches to their elimination or mitigation, and economic and other adverse impacts on affected parties. In addition, rigorous cost-benefit analyses assure that regulations or standards are warranted, and establish that the proposed approach is the most cost-effective. R&D can also foster the development of tools and procedures to reduce costs borne by the government, and for the affected parties in certification, inspection and enforcement activities associated with regulations.

R&D Directly Responsive to National Needs. A large portion of the Department's research is primarily intended to bring about substantial technical improvements by

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5 *Strategic Plan,* pp. 63-65.

6 *Ibid,* p. 63.

direct stimulation of significant innovation in the transportation enterprise, rather than through mandated functional responsibilities. For example, the Department is extensively involved in guiding and shaping public investment in the transportation infrastructure through trust fund grants. More than $75 billion is spent annually by all levels of government on maintenance and construction of highways: about one-fifth of this amount is federal funds. R&D that reduces the cost and extends the performance and lifetime of roadways and other transportation infrastructure can be a very worthwhile investment.

DOT research and technology initiatives can play a significant part in stimulating and accelerating activity in the private sector, resulting in major innovations in transportation. Although development of advanced transportation technology and improved operations is largely the responsibility of non-federal government entities and the private sector, focused federal investment in research, development, testing, evaluation, and prototype deployment can have significant impacts. This is particularly true when market-driven R&D efforts are delayed by technological and other uncertainties or institutional impediments.

In order to make the most useful contribution to the Department's mission and strategic goals, these research and technology activities must be guided by a sound and comprehensive management strategy. The *Strategic Plan* identified six specific actions that the Department will be taking over the five-year period to implement an effective research and technology management strategy. These actions are:

(1) implementing a strategic planning and management process that will include developing the *S&T Strategy*, the Department's *R&D Plan* (this document), and bench marking efforts for several major public-private R&D partnerships;
(2) improving the efficiency and effectiveness of the Department's R&D facilities and programs;
(3) promoting the exchange of information on transportation R&D via an Internet 'home page' and a tracking system for DOT projects;
(4) forging technology-based, public-private R&D partnerships;
(5) supporting multi-modal enabling research activities; and
(6) creating an expanded education and training program for students, transportation professionals, and the general public.

(1) Strategic Planning: A focused strategic planning and management process will assure that both the Department itself, as well as the wider federal and national transportation R&D communities, are in agreement with the goals, policies, plans and resource levels made available for this purpose. This process will also develop performance indicators for assessing the efficiency and effectiveness of transportation R&D projects.

Within DOT, the primary mechanism for achieving this is the Research and Technology Coordinating Council, or RTCC. This Council regularly brings together senior officials from the offices managing research and technology activities for major DOT elements to discuss issues of common interest, set program directions, and act as a forum for reviewing the Department's R&T plans and activities. Within the federal government this same role is fulfilled by the NSTC and its Committee on Technology, which in turn has a Transportation R&D subcommittee.

As part of this process, several documents are being prepared and will be regularly updated to provide the latest guidance and information on transportation R&D. The *DOT Research and Development Plan* describes the Department's R&D activities in the context of its *Strategic Plan*. Two related documents – the *National Transportation Technology Plan* and the *National Strategic Research Plan* -- describe major new transportation technology partnership initiatives and enabling research activities, respectively, in the context of the NSTC *S&T Strategy.*

(2) World-Class Transportation R&D Capability: Since much of the Department's R&D is undertaken at its own research and technical facilities, it is important that these institutions reflect the highest standards of competence and ability. To achieve this goal, these institutions will be exploring a number of well-recognized quality programs to establish standards of excellence for themselves. Among these are: ISO 9000 certification, Malcolm Baldridge Award and President's Quality Award criteria, Capability Maturity Modeling (CMM), and bench marking. The major DOT research facilities are as follows:

Civil Aeromedical Institute (FAA)
Oklahoma City OK, http://www.cami.jccbi.gov

Transportation Technology Center (FRA)
Pueblo CO, http://www.aar.com

Turner Fairbank Highway Research Center (FHWA)
McLean VA, http://www.tfhrc.gov

U.S. Coast Guard Research and Development Center (USCG)
Groton CT, http://www.rdc.uscg.mil

Vehicle Research and Test Center (NHTSA)
East Liberty OH, http://www.nhtsa.dot.gov

Volpe National Transportation Systems Center (RSPA)
Cambridge MA, http://www.volpe.dot.gov

William J. Hughes Technical Center (FAA)
Atlantic City NJ, http://www.tc.faa.gov

(3) Information Exchange: Several steps are being taken to disseminate information about the Department's R&D programs more widely. A DOT science and technology Internet home page is available,[7] and includes links to several related transportation R&D sites both within and outside the Department. The 'Research and Development in the United States' (RADIUS) database is being made accessible to all DOT R&D program personnel. This database, developed by the Rand Corporation for the federal government, includes information about federal R&D projects. Access to this database will enable DOT personnel both to enter and retrieve important federal R&D information. An R&D tracking system is also being studied within the Department, and a pilot version should be operating by the end of 1998.

(4) Public-Private Partnerships: As mentioned earlier, the annual *National Transportation Technology Plan* will incorporate the latest information on major transportation R&D initiatives. In addition to the initiatives identified by the NSTC in the *S&T Strategy*, however, DOT is active in a number of current and ongoing partnerships of this nature. These activities are described in greater detail in the following chapter (Chapter III).

(5) Enabling Research: The annual *National Strategic Research Plan* will provide updated information on the status of federal transportation-related enabling research activities. This topic is described in greater detail in Chapter IV.

(6) Education and Training: Finally, an important component of the Department's R&D management strategy is assuring that there is a continuing investment in the skills and abilities of the professionals responsible for designing, constructing, operating and maintaining our nation's transportation system – a work force that consists of more than ten million persons.[8]

B. The Transportation Science and Technology Strategy

The DOT R&D program takes place in concert with a wide variety of transportation research activities throughout the executive branch. The NSTC Committee on Transportation Research and Development (CTRD) provided a vehicle to assure effective coordination of these activities.[9]

Chaired by Deputy Secretary of Transportation Mortimer Downey, the NSTC Committee on Transportation R&D developed the first *Transportation Science and Technology Strategy* in November 1997. This document was intended to help Congress, the White

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7 At *http://scitech.dot.gov*. Additional information on R&D activities can be found through the home pages for the Department's modal administrations, which are accessible through *http:/www.dot.gov*.

8 Bureau of Transportation Statistics, *National Transportation Statistics 1997*, pp. 87-90.

9 The CTRD became a subcommittee under the new NSTC Committee on Technology effective February 1, 1998.

House, and federal agency heads to establish national transportation R&D priorities and coordinated research activities. The *S&T Strategy* provides a vision of the national transportation enterprise, a likely scenario for this national transportation enterprise in the year 2020, and a series of national-level goals and measures that will help the nation achieve this vision and future.

The *S&T Strategy*'s scenario for transportation in the year 2020 was based on the projected impacts of several global trends. There would be a significant increase in the world's population, especially in urbanized areas of the developing world, accompanied by a shift to an older population (on average age) in the developed world. A new class of middle and upper income-earners would emerge, particularly in the industrializing Pacific Rim area. This newly affluent group, concentrated in cities, would spur a continued demand for private motor vehicles. Growth on both tourism and international trade would put major strains on the physical infrastructure in many regions.

After establishing this scenario, the *S&T Strategy* then describes the extent to which technologies could help to mitigate concerns and take advantage of system-wide opportunities. Five specific transportation strategic goals and their accompanying measures of success were presented: safety, security, environmental quality and energy efficiency, economic growth and productivity, and access and mobility (See *Figure II-7)*.

The actual implementation of this Transportation Science and Technology Strategy is based on a four-tiered approach:

1. *Strategic Planning and System Assessment*,
2. *Strategic Partnership Initiatives*,
3. *Enabling Research*, and
4. *Transportation Education and Training.*

Figure II-7

NSTC STRATEGIC GOALS

1. **Provide a safer transportation system.**

2. **Achieve a high level of transportation system security.**

3. **Improve environmental quality and energy efficiency.**

4. **Foster economic growth and productivity through more effective and flexible global passenger and freight services.**

5. **Ensure improved access *to* and increased mobility *on* the Nation's transportation system.**

The first element, *Strategic Planning and System Assessment*, focuses on establishing and assessing transportation goals in accordance with a dynamic external environment. This requires the establishment of a permanent mechanism by which an ongoing dialogue about the goals, performance and needs of the transportation system can take place among both public and private sector members of the transportation community. In this way, the goals and measures for R&D can be regularly updated to reflect the most current status of transportation trends and activities.

The second element, *Strategic Partnership Initiatives*, seeks to combine public and private resources to expedite the application of research advances. Eleven strategic partnership initiatives in the areas of information infrastructure, next-generation vehicles, and physical infrastructure have already been identified. *(See Figure II-8).* These initiatives also directly address one or more of the five major national goals established by the NSTC. Additional information on the current list of these *Strategic Partnership Initiatives* can be found in the NSTC N*ational Transportation Technology Plan.*

The third element of the four-tiered strategy, *Enabling Research*, identifies potential research areas that could bring significant benefits to transportation operations. These research areas share several characteristics: they support long-term national transportation goals; however, their benefits are too dispersed or too far in the future, and the cost or risk is too great, to motivate a single entity, public or private, to undertake a major effort. Thus, these projects would be best pursued by a partnership of both public and private sector participants.

Figure II-8

NSTC STRATEGIC PARTNERSHIP INITIATIVES

I. Information Infrastructure

1. *Intelligent Vehicle Initiative*
2. *National Intelligent Transportation Infrastructure*
3. *Next-Generation Global Air Transportation*
4. *Enhanced Transportation Weather Services*
5. *Enhanced Goods and Freight Movement at Domestic and International Gateways*
6. *Accessibility for Aging and Transportation-Disadvantaged Populations*

II. Next-Generation Vehicles

7. *Next-Generation Surface and Marine Transportation Vehicles*
8. *Aviation Safety Research Alliance*

III. Transportation Physical Infrastructure

9. *Total Terminal Security*
10. *Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure*
11. *Transportation and Sustainable Communities (combines 'Environmental Sustainability of Transportation Systems' with 'Local Environmental Assessment Systems')*

The six current *Enabling Research* areas identified by the NSTC are depicted in *Figure II-9*. Additional information on the current list can be found in the NSTC *National Transportation Strategic Research Plan*.

Finally, the fourth element, *Transportation Education and Training,* ensures a continuing investment in the skills and abilities of the professionals responsible for designing, constructing, operating and maintaining our nation's transportation system -- a work force that consists of more than ten million persons. The Department is currently developing a National Transportation Education Strategy, which will be published and initially implemented in 1999. A major focus of this Strategy is the Garrett A. Morgan Technology and Transportation Futures Program[10]. This effort, named after an African-American engineer and inventor, seeks to make available information about promising careers in transportation to over one million students of all

[10] At *http://education.dot.gov.*

ages, and to encourage them to improve their math, science and technology skills by the year 2000.

The Department will develop partnerships with the transportation and educational communities to offer access to these skills in local schools through such activities as donating computer equipment and software, mentoring and tutoring programs, and information about transportation careers. This effort will also incorporate efforts to reach those not directly part of the transportation work force, especially students and users of transportation services, so that they can both understand and better appreciate the role of transportation in their lives.

Figure II-9

NSTC ENABLING RESEARCH AREAS

1. *Human Performance and Behavior*
2. *Advanced Materials*
3. *Computer, Information, and Communication Systems*
4. *Energy and Environment*
5. *Sensing and Measurement*
6. *Tools for Transportation Modeling, Design, and Construction*

In addition, the NSTC has recommended four new major initiatives in this area. They are: (1) introducing transportation concepts in elementary and secondary school curricula; (2) collaborating with vocational schools, community colleges and industrial training institutes in enhancing transportation-related instruction; (3) promoting the creation of transportation college degree programs based on multidisciplinary curricula with an international focus; and (4) enhancing mid-career training opportunities for transportation professionals to stay current in the latest technologies.

Since 1987, the Department of Transportation has been investing in the University Transportation Centers (UTC) program. This is a nationwide network of ten regional university-based research consortium consisting of six to twelve universities each, with a research and education focus based on that region's transportation needs. The TEA 21 (Transportation Equity Act for the 21st Century) legislation authorizes $192 million for university transportation research over the next six fiscal years.

In addition to the UTCs, nearly every DOT administration has close relationships with a number of colleges and universities which specialize in research and training in that mode of transportation. For example, the FAA has established a number of Centers of Excellence for aviation transportation studies in areas such as: traffic flow management, navigation, human factors, environment and energy, aircraft structural modeling, and aviation system reliability. Among the participating institutions are: Drexel, Iowa State, Northwestern, Ohio, Rutgers, Stanford, Tuskegee and Wayne State Universities; the Georgia and Massachusetts Institutes of Technology, Virginia Polytechnic Institute, and the Universities of California and Maryland. In addition, two DOT administrations manage their own professional service academies: the U.S. Merchant Marine Academy (MARAD) and the U.S. Coast Guard Academy (USCG).

Together, these and similar institutions provide the Department with a readily-accessible source of knowledge and ideas for improving the nation's transportation system and training future generations of transportation professionals in all needed skill areas. In order to perform these vital missions even more successfully, these institutions are encouraged to incorporate the latest in enabling transportation technologies into their curricula and research agendas. A selected list of these topics, drawn from the six enabling research areas and discussed later in this report, is depicted in *Figure II-10.* Information on these topics and their applications to transportation could also be introduced into the curricula of selected elementary and secondary school classes through the Garrett A. Morgan Program and other similar activities.

The Department's research and technology programs are a core element of its overall strategy for the next century. They will assist the Department and the larger transportation community to meet the challenges and take advantage of the opportunities to come. And in doing so, the Department will be able to achieve its goal of a visionary and vigilant Department of Transportation — ONE DOT that is international in reach, intermodal in form, intelligent in character, and inclusive in nature.

But the Department does not act alone. Meeting the strategic goals will require ongoing partnerships with the private sector; state, local, and tribal governments; consumers; universities; and other federal agencies. Only through such strategic research partnerships can the Department respond to one of the greatest challenges facing transportation — how to do more with less in building a 21st century transportation system that ensures America will remain prosperous and be the most mobile nation in the world.

Figure II-10

SELECTED ENABLING RESEARCH TECHNOLOGY AREAS

1. Human Performance and Behavior

- Effects of fatigue and stress, such as those of railroad personnel, ground vehicle drivers, ship crews, air traffic controllers, and pilots.
- Driver behavior and errors, especially for the aged, functionally impaired, and young.
- Communications problems, e.g., coordination among pilots and air traffic controllers, and among marine pilots and bridge vessel teams.
- Human-machine interactions among drivers and future vehicles, airport screening personnel, and air traffic controllers with new systems.

2. Advanced Materials and Structures

- High performance concrete and asphalts, new steel and aluminum alloys, and composites, for pavements, airports, and rails and rail wheels.
- Micro/nanotechnologies such as those for low cost miniature components and atomic-level coatings of metallic surfaces.
- Ultra fire-resistant materials for aircraft.
- New occupant protection and explosive hardening structures and passenger air bags.

3. Computer, Information, and Communication Systems

- Traffic control and management systems for aviation and highways.
- New navigation and control systems, such as the Global Positioning Systems, other satellites, augmentation systems, and their coverage in interference environments.
- New vehicles and vehicle control systems for cars, trucks, buses, railroads, and ships.
- Low cost surveillance systems for ground vehicles and airport surface traffic.
- Collision avoidance and crash mitigation systems for ground vehicles.
- Catastrophic damage mitigation for aircraft and aircraft engines.
- Modern communication systems, such as spectrum efficient radios and digital data links.
- Smart cards and other personal and vehicle identification technologies.
- Weather analysis and forecasting for aviation, ships, and highways.

Figure II-10 (cont.)

SELECTED ENABLING RESEARCH TECHNOLOGY AREAS (Cont.)

4. *Energy, Propulsion, and Environment Engineering*

- Electric, hybrid, and light weight vehicles.
- Alternative low emission and low consumption fuel technologies, such as fuel cells, storage batteries, and flywheels.
- Noise reduction systems for aircraft, helicopters, and trains.

5. *Sensing and Measurement*

- Monitoring highway and urban traffic movement.
- Identifying ground vehicle and aircraft hazards.
- Automatically assessing the quality of pavements, bridges, and other structures.
- Sensing vehicle emissions and gases and vapors in subways and transit tunnels
- Weather, pollution, and explosives sensing for aircraft and ground vehicles.
- Ocean current sensing for search and rescue.
- Zero or low visibility sensing at night or in fog for aircraft, ships, and ground vehicles.
- Low cost alcohol and drug detection systems.

6. *Analysis, Modeling, Design and Construction Tools*

- Modeling operational environments, such as vehicle and driver behavior and locomotive engineers.
- Analyzing crash injury dummies and air bag protection for vehicles and aircraft.
- Airport passenger and bag flow analysis.
- Fuel savings, emissions, and emission forecasting for aircraft and highways.
- Aircraft wake vortex modeling.
- Transportation simulations for air traffic, transit, highways, and urban areas.

CHAPTER III: Partnership Initiatives and Technology Sharing

A. Focus Areas for New Partnership Initiatives

The NSTC *S&T Strategy* identifies eleven specific partnership areas that can expedite the research process and speed up the introduction of much-needed new transportation technologies. These partnership initiatives address recognized national needs, have a technology focus, and, if successful, could rely on existing market forces and the private sector for widespread implementation. In each case, the initiative would benefit the nation as a whole and could not proceed in a timely fashion without some cost-shared federal support of the overall efforts. The initiatives are intended to incorporate and guide ongoing activities that are relevant to their goals — with any new federal support to be developed within the overall funding limits and constraints already established.

The partnership initiatives fall into two broad categories: (1) those representing a broadened view and context for existing federal R&D; and (2) new efforts requiring further definition and interagency coordination. Five initiatives represent existing, well-established DOT programs. In these areas, the Committee's primary focus has been relating the initiatives to a broader overall transportation research agenda, folding them in with other related federal programs, and, where appropriate, expanding their scope or coupling activities that have natural linkages or synergy. These five initiatives are:

1. *Aviation Safety Research Alliance,*
2. *Next Generation Global Air Transportation,*
3. *National Intelligent Transportation Infrastructure,*
4. *Next Generation Surface and Marine Transportation Vehicles, and*
5. *Intelligent Vehicle Initiative.*

The other six partnerships represent areas in which the various interagency teams identified topics of significant importance and near-term opportunity, but which require a large degree of coordination and stimulation to define and implement integrated actions by several agencies. For these, work of the past several months has emphasized extensive outreach to bring about awareness of the initiative within the transportation and research communities and to assure understanding of those communities' needs.

Future activities and progress will depend largely on both the availability of funding and continued encouragement of coordinated efforts. These six initiatives are:

6. *Accessibility for Aging and Transportation-Disadvantaged Populations,*
7. *Enhanced Goods and Freight Movement at Domestic and International Gateways,*
8. *Enhanced Transportation Weather Services,*
9. *Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure,*
10. *Total Terminal Security, and*
11. *Transportation and Sustainable Communities.*

The table at the end of this section summarizes the relationship between the eleven partnership initiatives and the Department's broad strategic goals, outcome goals, and current R&D programs. For those initiatives representing new R&D activities, the "DOT Programs" refer to efforts with the same overall focus as the initiative and on which a framework for the new initiative may be built.

1. Aviation Safety Research Alliance

Vision: An even safer aviation system that accommodates continued growth in air traffic while experiencing fewer aircraft accidents and related fatalities.

Goal: Identify methods that, when implemented, would reduce the fatal aviation accident rate by 80 percent by 2007, as compared to the 1990-1996 baseline.

Participants: FAA (DOT lead) and NASA. Also DOD, DOE, DOC (NIST), NWS, U.S. Bureau of Mines, International Civil Aviation Organization, aircraft and avionics manufacturers, airlines, aviation organizations, universities.

Great strides have been made over the past forty years to make flying the safest of all major modes of transportation. Aviation accidents have leveled off at extremely low rates. Yet, although the rate of accidents is very low, it has remained relatively constant for the past decade. At the same time, air traffic has grown rapidly, and should continue to do so well into the foreseeable future. Coupled with the constant accident rate, the projected growth in air traffic could result in a dramatic increase in accidents — with perhaps as many as 4,500 fatalities worldwide annually by 2025.

On February 12, 1997, the White House Commission on Aviation Safety and Security issued its final report to President Clinton, calling for a reduction in the fatal aviation accident rate by 80 percent within the next 10 years. Aviation safety programs have been under way for many years within the FAA, DOD, and NASA, as well as the private sector and universities. These efforts have been successful in holding constant the aviation accident rate and in countering potential safety problems associated with the introduction of new technologies. However, reducing this rate by 80 percent requires a truly integrated partnership among federal agencies and the support of both industry and academia. This initiative will meet this challenge by: (1) identifying and conducting research needed to meet the national safety goal; and (2) working with industry to deploy research results in the form of new safety technologies.

Five broad areas of aviation safety research are addressed by this initiative:

- *Human Error Prevention:* This research addresses means of preventing accidents due to human error. Programs seek to quantify and predict the susceptibility of automated systems to human error; to develop design guidelines for such systems; to reduce the consequences of flight crew errors through better flight deck designs; to develop improved methods of training pilots and maintenance crews; to develop work scheduling tools and other countermeasures that promote alertness and enhance performance; and to improve rotorcraft pilot performance through improved displays and other technological aids.

- *Flight Critical Systems and Information Integrity:* These research programs are developing a number of safety technologies, including systems to prevent accidents due to unexpected failures, damage, or upset situations; more durable engine materials and components; technologies that extend the useful safe life of aircraft structures, airframes, and engines; technologies that assure the integrity of flight information; and sensing and processing technologies to aid in aircraft monitoring.

- *Weather:* Research in this area is reducing weather-related accidents through technologies that communicate and display real-time weather information to airborne and ground-based users; eliminating visibility-induced errors through synthetic and enhanced vision displays, worldwide terrain databases, and Global Positioning System navigation; improving the effectiveness of ice-protection systems and reducing development costs for the industry; and developing and validating technology to detect atmospheric turbulence and to mitigate its effects on commercial aircraft.

- *Human Survivability:* These efforts seek to ensure human survivability should an aircraft accident occur. Specific programs are developing advanced fire prevention, detection, and suppression methods; a systems approach to aircraft crashworthiness that includes new structural concepts and materials, safer cabin designs, advanced restraint equipment, and a validated analysis methodology; and a systems approach to passenger evacuation comprising computer simulation and improved procedures, training, equipment, and design criteria.

- *System-wide Monitoring, Modeling, and Simulation:* This research is developing advanced tools for converting aviation safety data into operationally useful information; tools, services, and standards for sharing data across the National Airspace System; and valid measures of unsafe incidents and conditions that may be accident precursors.

2. Next Generation Global Air Transportation.

Vision: A safer, more efficient airspace system that meets the growing demands of global air transportation.

Goal: Achieve a global air transportation system that supports the "Free Flight" concepts embodied in the FAA's Free Flight Phase One program and the FAA/NASA Interagency Air Traffic Management Integrated Product Team plans.

Participants: FAA (DOT lead) and NASA. Also DOD, NWS, airlines, aircraft and avionics industries, academia, International Civil Aviation Organization.

Many factors will challenge our ability to operate the National Airspace System, or NAS, safely and efficiently. For one, the FAA expects that world revenue passenger miles will increase by 64 percent between 1997 and 2008. To meet this demand, airlines will increase the hours flown by their large aircraft by as much as 52 percent. And despite the use of larger and heavier aircraft to accommodate demand, airlines' aircraft inventories are projected to increase by 50 percent in the coming decade.

Air transportation is essential to the nation's economic well-being. Since 1960, the U.S. gross domestic product has grown 14-fold and U.S. exports 30-fold. Today, American exports total more than $580 billion a year. Such growth is made possible by safe, reliable, and consistent air transportation. In this era of global economies, air transportation makes it possible to move quickly millions of people and billions of dollars of goods to markets around the world. The challenge today is to keep ahead of this growth in globalization by getting people and freight anywhere in the world safely, efficiently, and at a reasonable cost.

Anticipating the future growth in air traffic, this initiative implementsthe Free Flight Phase One program, a precursor of "free flight". This term refers to an airspace system that greatly increases user flexibility to plan and fly preferred routes, saving both fuel and time and affording more efficient use of airspace. Indicators suggest that "free flight" will yield significant benefits to system users by: (1) removing constraints and restrictions on flight operations; (2) improving the exchange of information and collaborative decision making among users and air traffic managers; and (3) providing tools and models to aid air traffic service providers. The initiative also embodies the research in the FAA/NASA *Integrated Plan for Air Traffic Management Research and Technology Development*, which — when combined with other initiatives in communications, navigation, human factors, and next generation weather concepts — will satisfy the future needs of the aviation community.

Undertaken in cooperation with the aviation industry, this initiative will develop both the air traffic management and the communications, navigation and surveillance systems required to make "free flight" a reality. Such a system would allow air traffic service providers to manage system resources strategically, in conjunction with users, to achieve maximum safety and efficiency.

This initiative comprises the following major sets of activities:

- *Technology Integration:* At its most basic level, "Free Flight Phase One" refers to the integration of a variety of technologies and programs that provide critical air traffic information: state-of-the-art digital communications, automated decision-making tools for air traffic control and flight planning, automatic dependent surveillance, navigation satellites, weather information processors, and cockpit displays for all phases of flight.

- *Demonstration of Operational Capabilities:* This activity essentially transfers the free flight concept to an operational setting prior to full deployment. In 2000, "Free Flight" capabilities will be demonstrated in oceanic airspace over Alaska and possibly other locations; these airspaces offer the dual advantages of a controlled environment and a variety of weather conditions and terrain. More than 2,000 aircraft will be equipped with the necessary cockpit displays, new voice cockpit communication equipment, and other avionics.

- *Evaluation and Validation:* Based upon the results of the operational demonstrations in Alaska and Hawaii, and possibly other locations, this activity will either validate the Free Flight Phase One concept for full system implementation, or it will identify necessary changes to the proposed technologies, supporting methodologies, or functional capabilities.

3. National Intelligent Transportation Infrastructure

Vision: A truly seamless intermodal surface transportation system that accommodates private, public, and commercial vehicles, and permits increasing communication and cooperation between infrastructure and vehicles.

Goals: Reduce traffic crashes and fatalities; reduce travel time for all transportation system users; increase overall transportation system throughput; reduce the costs of operating and using the surface transportation system.

Participants: ITS Joint Program Office (DOT lead), FHWA, FRA, FTA, NHTSA, USCG. Also state DOTs, Metropolitan Planning Organizations, emergency response and law enforcement agencies, industry.

Surface transportation in the U.S. faces a number of challenges. Despite the fact that our country has one of the best roadway systems in the world, congestion is increasing, and safety remains a serious problem. Congestion takes its toll in lost productivity, costing the nation about $40 billion a year. Traffic crashes represent a $150 billion financial burden to the economy and each year result in the loss of 40,000 lives.

Intelligent Transportation Systems, or ITS, offer promising solutions to these problems. However, no single technology "fix" can meet America's growing demand for travel. Although individual ITS products and services have their unique merits, it is important that they be seamlessly integrated to support multimodalism and intermodalism in metropolitan and rural areas and on interstate corridors.

This initiative is developing a communication and information "backbone," a National Intelligent Transportation Infrastructure (NITI), that will enable ITS products and services to work together to save both time and lives. The NITI refers to the integrated electronics, communications, and hardware and software elements that can support ITS. Related activities within DOT include the Nationwide Differential Global Positioning System Initiative. Analogous to the local- and wide-area networks used in many workplaces, the NITI will allow surface transportation to be managed seamlessly by integrating information systems across both modal and jurisdictional lines — within a region and, where appropriate, across the country. Although travelers throughout the country are already using ITS, no area or region has all of the three major NITI components in place. These three components are the Metropolitan Intelligent Transportation Infrastructure, the Commercial Vehicle Operations Infrastructure, and rural applications and infrastructure.

There are six fundamental elements of this partnership initiative:

- *Showcase NITI Benefits:* This effort will demonstrate the benefits of integrated regional travel management and travel information systems at four metropolitan sites: Seattle, Phoenix, San Antonio, and New York City. Similarly, it will showcase seven commercial vehicle deployments initiated in 1996 in California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, and Washington/Oregon.

- *Create Funding Incentives:* The Transportation Equity Act for the 21st Century (TEA 21) of 1998 includes an incentive funding program targeted at the integration of ITS functions in metropolitan areas, rural communities, and commercial vehicle operations. The program calls for a 50 percent match by the local authority. The matching funds can be either private investments or other public funds; however, no more than 80 percent may come from federal sources.

- *Build Professional Capacity:* Because there are not enough professionals with the skills necessary to support the delivery of ITS services, professional capacity building is crucial to establishing an NITI. Under this initiative, a number of workshops and seminars are being held across the country or are in the development stage.

- *Provide Technical Assistance:* Partners in this initiative are supporting ITS implementation among state and local authorities through guidance and documentation on project planning, technology procurements, enabling technologies, and innovative financing.

- *Accelerate Standards Development:* Completed in 1996, the National ITS Architecture defines those areas in which standards would promote ITS interoperability and integration. Based on these requirements, and working closely with users and manufacturers, DOT initiated a program to accelerate standards-setting, resulting in initiating 50 new standards in 1997 and several others to be developed over the next three years.

- *Establish Conformity Criteria for Architecture and Standards:* A key effort of this initiative will be to identify criteria so that localities can ensure that their regional frameworks conform to the National ITS Architecture and agreed-upon standards.

4. Next Generation Surface and Marine Transportation Vehicles

Vision: A far more sustainable transportation system with fewer harmful environmental impacts and reduced dependence on fossil fuels.

Goal: Develop internationally competitive, domestically produced motor vehicles and ships that achieve unprecedented gains in fuel efficiency and in both environmental and operational performance.

Participants: RSPA (DOT lead), FRA, FTA, FHWA, NHTSA, MARAD, USCG. Also DOC; DOD; DOE; EPA; NSF; DOI (National Park Service); vehicle, engine, and fuel-cell manufacturers; fuel producers; component suppliers; shipyards; state and local agencies; universities.

As the world's reliance on motor vehicles has grown, so have concerns about concomitant increases in petroleum consumption, carbon emissions, and air pollution. Addressing these problems requires significant advances in vehicle technology. This initiative responds to this need through research leading to the development of highway vehicles, locomotives, and ships that are better designed, more fuel-efficient, and less polluting.

Highway Vehicles: This effort will continue the Partnership for a New Generation of Vehicles (PNGV) and advanced bus propulsion systems research activities and supplement them by also focusing on improvements in medium- and heavy-duty vehicle fuel efficiency. A proposed joint DOT/DOE program, the Advanced Vehicle Program (AVP), would continue the development and demonstration of a range of advanced technologies for medium and heavy duty vehicles. It would also focus on commercial as opposed to military vehicles with the objective of significantly reducing emissions, including greenhouse gases, while improving fuel efficiency and industry competitiveness.

Locomotives: U.S. applications for high-speed trains require a non-electric high-acceleration locomotive. This initiative will support the development, test, and demonstration of non-electric high-speed technology to establish a technological context in which state and local governments and industry can implement new rail services.

Ships: The Administration's shipbuilding program includes an R&D element, MARITECH, that focuses on advanced ship designs and shipyard modernization. Additional research needs to address not only ship structure but ship systems. An aggressive program to demonstrate and develop the marine application of fuel cells has led to a partnership among the Departments of Transportation, Defense, Commerce, and Energy. This program will develop fuel-cell technology for wider use in the government fleet and for transfer to the private sector.

This initiative comprises vehicle research and technology activities in the following areas:

- *PNGV/Light truck Clean Diesel Program/AVP:* This research seeks to apply advanced technologies and concepts to improve dramatically the fuel efficiency of automobiles and trucks (light, medium and heavy-duty) while maintaining safety and performance. Specific activities will address lightweight materials, crashworthiness, energy conversion and storage, emission control, and advanced manufacturing technologies.

- *Advanced Buses*: This effort is developing, demonstrating, and fostering the commercialization of low- and zero-emission transit buses. Work includes the development of fuel-cell propulsion systems and prototype 40-foot fuel-cell buses; research on the safe handling of fuel for fuel cells; and accelerated demonstrations of hybrid-electric and all-electric transit bus technologies.

- *Next Generation High-Speed Rail*: This program is developing and validating cost-effective high-speed (125-150 mph) passenger rail technology that can operate on the existing infrastructure. A principal objective is to make proven high-speed technologies available for implementation by 2000. Activities include demonstrating the operating and maintenance characteristics of non-electric locomotive designs, demonstrating the operability of flywheel energy storage, and testing active locomotive noise control.

- *Ship Building and Ship Structure*: This activity, part of the MARITECH program, is developing improvements in commercial ship design and in shipyard facilities, processes, and procedures.

- *Marine Application of Fuel Cells:* This effort is developing, testing, and installing affordable, highly efficient, low- or zero-emission shipboard fuel cell power and propulsion systems. The first phase will develop and test a conceptual design and components for a fuel cell power plant that can operate on naval diesel fuel. Phase two will design and build a reduced-scale fuel cell power plant and perform land-based tests. The final phase will demonstrate the diesel-fed fuel cell in a marine environment.

5. Intelligent Vehicle Initiative

Vision: A roadway system where Americans operate in a significantly safer environment and enjoy greater mobility and efficiency.

Goal: Reduce the number of highway crashes and resulting injuries and fatalities.

Participants: ITS Joint Program Office (DOT lead), FHWA, FTA, NHTSA. Also motor vehicle and trucking industries, state DOTs, local agencies.

The personal, social, and economic costs of motor vehicle crashes include pain and suffering; direct costs sustained by the injured persons and their insurers; indirect costs to taxpayers for health care and public assistance; and, for many crash victims, a lower standard of living and quality of life. During the past two decades, motor vehicle crashes accounted for over 90 percent of all transportation fatalities and an even larger percentage of accidents and injuries. More than 40,000 people die each year in highway crashes, with a total economic loss estimated at over $150 billion annually. In addition, 30,000 bus crashes over the past five years resulted in 17,000 deaths and injuries. Driver error is cited as the primary cause in about 90 percent of all police-reported crashes involving cars, buses, and trucks.

Research indicates that collision-avoidance systems offer the potential for significantly reducing motor vehicle crashes. Such systems may warn drivers, recommend control actions, or introduce temporary or partial automated control of the vehicle in hazardous situations.

This effort, the Intelligent Vehicle Initiative, or IVI, is a government–industry program to accelerate the development and commercialization of these safety- and mobility-enhancing systems. The overall emphasis is on four areas: (1) research and evaluation of the benefits of IVI services; (2) development of industry-wide standards: (3) integrated system prototyping; and (4) field test evaluations of the most promising products.

Ongoing and recently completed work on crash avoidance, in-vehicle information systems, automated highway systems, and motor carrier safety provides a strong foundation for intelligent vehicle research. The IVI will continue and expand these efforts, particularly in areas such as human factors, sensor performance, modeling, and driver acceptance. The broad program elements include the following:

- *Crosscutting Activities:* Guiding and influencing all other program elements, these include architecture and standards development; research, development, and testing in human factors and technology; acquisition, expansion, and validation of simulation models and other evaluation tools; development and implementation of evaluation plans for field operation; outreach activities; and program planning and administration.

- *Development of Services:* This covers the research, development, testing, and evaluation of individual crash-avoidance and efficiency-enhancing systems, including rear-end, road-departure, lane-change, merge, intersection, and railroad-crossing collision avoidance; vision enhancement; location-specific alerts and warnings; automatic collision notification; smart restraints; real-time traffic and traveler information; vehicle stability warning; vehicle diagnostics; automated transactions; obstacle/pedestrian detection; navigation and routing; cargo identification; transit passenger monitoring; and precision docking.

- *Selection of Services for Integration:* This represents the selection of specific intelligent vehicle services, and a mix of services, to be included in integrated packages. The selection involves extensive work on estimating benefits and costs and user acceptance.

- *System Design and Development:* Two types of activities are included in this category: 1) research, development, and prototype testing to assess intelligent vehicle capabilities; and 2) developing system and subsystem specifications for the vehicles and infrastructure modifications necessary for operational tests.

- *Operational Tests and Evaluation:* Work in this area implements the plans for field tests on actual highways, evaluates the integrated intelligent vehicle services subject to the operational tests, develops deployment plans, establishes performance thresholds, and develops recommendations.

- *Product Deployment:* This refers to the actions by manufacturers and their suppliers to make and offer intelligent vehicle systems in production motor vehicles. It is anticipated that the systems will be adopted by manufacturers as part of their standard product line. Product deployment also includes the installation of infrastructure-based components by regional, state, and local highway agencies. This activity is the final step and ultimate objective of the IVI.

6. Accessibility for Aging and Transportation-Disadvantaged Populations

Vision: A transportation system that meets the mobility needs of the elderly, the poor, persons with disabilities, and all other Americans without access to a private automobile.

Goal: Create a model seamless regional transportation system that serves the needs of the elderly and transportation-disadvantaged while optimizing the existing human and capital investment in paratransit.

Participants: FTA (DOT lead), FHWA, NHTSA, ITS Joint Program Office. Also HHS, HUD, Metropolitan Planning Organizations, Area Agencies on Aging, transit agencies, information and communication system vendors and integrators, private transit providers, universities.

Although the United States possesses one of the safest and most extensive passenger transportation systems in the world, the system is unable to provide optimal mobility for selected and growing portions of the population. These segments include the elderly, the physically challenged, and the poor.

Government investment in paratransit has provided the vast majority of the transportation options available to these populations. *Paratransit* is typically defined as flexible-route, low- or medium-capacity vehicles serving a pre-determined group of people, such as the elderly, for a fee. Paratransit fills an important transportation gap for many. However, management strategies that do not optimize the use of drivers and vehicles have made such services costly and less than fully responsive to their riders' mobility needs.

This initiative will improve the regional mobility of the elderly and transportation-disadvantaged through the application of information technologies to paratransit operations and assets. Selected information technologies — including automatic vehicle location, geographic information systems, and computer-aided dispatch — will be integrated into a centralized regional control system to manage otherwise independent paratransit operators. Dispatching, monitoring, and fare collection for all paratransit services within a single region will be conducted from a regional mobility management center.

Partners in this initiative will undertake the following activities to facilitate this regional paratransit service:

- *Outreach:* This activity will bring together interested parties from all levels of government and the private sector to: (1) define the problem of providing regional paratransit services; (2) address the applicability of various ITS technologies; and (3) better understand the transportation needs of the affected populations. A workshop held on December 8, 1997, at the Massachusetts Institute of Technology in Cambridge, MA addressed the feasibility of regional paratransit for the elderly. Participants concluded that although the technology appears ready for such services, the need remains for greater coordination among paratransit providers.

- *Concepts for Model Deployment:* This will develop broad implementation strategies for promising regional paratransit concepts. It will develop the overall justifications; determine the applicability and availability of various technologies; identify existing systems or services that may be similar; and outline participants' roles and responsibilities.

- *Demonstration and Research Design:* This effort will develop and document the demonstration and research design to be employed, including performance indicators, for at least one of the concepts identified in the activity described above.

- *System Plan:* This will determine and document project resources, schedules, and milestones.

- *System Integration and Deployment:* This activity will involve acquisition engineering, installation, testing, and integration of the various components comprising concept development and deployment.

- *System Operation:* This effort will involve the introduction of the model system into revenue service.

- *Evaluation:* This activity will include assessing system performance (using the indicators specified in the Demonstration and Research Design) and documenting the research results.

7. Enhanced Goods and Freight Movement at Domestic and International Gateways

Vision: A more productive national economy afforded by a more flexible, efficient, and seamless freight transportation system.

Goals: Improve freight mobility at the nation's land borders; ensure diffusion of existing freight information technologies and networks; expedite the global flow of goods.

Participants: Office of Intermodalism (DOT lead), FAA, FHWA, FRA, ITS Joint Program Office, MARAD, USCG and RSPA. Also DOC, DOD, DOE, DOJ (INS), EPA, State Department, Treasury (U.S. Customs Service), USDA, state and local transportation agencies, port and airport authorities, the freight and shipping industries.

Several trends in the past decade have transformed the way that goods are transported across the globe. First and foremost is the growth in the volume of international trade. NAFTA, in particular, has led to unprecedented growth in trade and land border traffic: U.S. exports to Mexico have grown by 37 percent and to Canada by 34 percent. Containerization is another significant trend, having become the dominant mode of moving trade goods. Container loadings have been growing on average by more than 6 percent a year in the past decade, far outpacing growth in the available port infrastructure and container handling facilities. On highways, truck congestion has reduced freight mobility, with trucks on many key freight arteries accounting for as much as one-fourth of the daily traffic.

While congestion is creating severe freight bottlenecks, the process of moving freight is becoming increasingly information-intensive. The intelligence embedded in modern transportation equipment has infused all facets of the goods movement process. Already, these technologies have improved the logistics and management of moving freight and transformed the ability of trading partners to compete in global markets. For example, terminal automation has afforded tremendous productivity improvements, while electronic scheduling and dispatch have increased both capacity and equipment use.

Since the ISTEA legislation in 1991, an estimated $4.8 billion has been spent on freight gateway projects, with the federal share totaling about 24 percent. The TEA 21 legislation provides $140 million in both FY 1999 and FY 2000 for two new discretionary programs. Under the *National Corridor Planning and Development Program*, participating states and Metropolitan Planning Organizations (MPOs) will coordinate the planning, design and construction of corridors of national significance, economic growth, and interregional or international trade. Under the *Coordinated Border Infrastructure Program*, participating border states and MPOs will improve the safe movement of people and goods at or across the U.S. borders with both Canada and Mexico.

This partnership initiative builds on these efforts to promote the deployment of information technologies at freight gateways through the following concurrent research and technology activities:

- *Demonstrations and Pilot Programs:* These demonstrations are assessing full-scale, integrated information and communication technology and logistics improvements at key freight gateways.

- *Technology Applications:* Supporting the full-scale demonstrations, this research will apply advanced information and communication technologies to specific improvements at freight terminals, ports, border crossings, and trade corridors.

- *Technology Assessments:* This effort will characterize the information and communication technologies currently available, determine their potential for improving freight mobility at gateways, and identify any new technologies that need to be developed.

- *System Architectures:* This activity involves the development of detailed system blueprints for automated freight gateways and trade corridors.

- *Standards:* An integral part of each of the above activities, this work will ensure that technology improvements developed under this initiative support interoperable and standardized U.S. freight transportation networks.

- *Information Exchange:* An ongoing, cross-cutting activity, this involves coordination and information exchange among federal, state, local, and private partners.

8. Enhanced Transportation Weather Services

Vision: A transportation system that is significantly safer, with far greater capacity and efficiency, by reducing the impacts of adverse weather.

Goal: Develop seamless, cost-effective transportation weather information systems.

Participants: ITS Joint Program Office (DOT lead), FAA, FHWA, FRA, NHTSA, RSPA. Also DOD, NOAA, NWS, Iowa DOT and other state DOTs, Environment Canada,industry and transportation users.

The safety, mobility, and economic impacts of weather on transportation are considerable. According to the White House Office of Science and Technology Policy, or OSTP, each year weather causes or contributes to 6,000 fatalities on U.S. highways and 800 aviation-accident-related deaths. As every driver knows, weather has a particularly serious effect on road conditions. Despite the fact that North America spends more than $2 billion a year on snow and ice control, road accidents increase during bad weather by a factor of from two to five. According to the DOT General Estimating System (GES) database, in 1995 alone highway accidents due to adverse road conditions resulted in more than 435,000 injury-related crashes.

Adverse weather increases highway travel times, boosts drivers' anxiety, and severely impacts road safety. Studies show that travelers' greatest needs are for detailed, timely, and accurate information on road and weather conditions. Within the ITS program, there are five projects which incorporate weather information as a core system design element. Of these, the Weather Information for Surface Transportation project, also known as FORETELL, has the most comprehensive adverse weather component.

A partnership among the FHWA, Iowa DOT, and the private sector, the FORETELL initiative will demonstrate and evaluate a system that will provide such information — first within a "pilot" Midwestern region, then over multiple regions, and eventually throughout North America. The program's first phase will deploy a road and weather information system across five states in the Mississippi Valley region plus western Ontario: a total land area of almost 750,000 square miles. Fully integrated within a wider suite of ITS services, this system will make use of state-of-the art weather radars and observing systems, including the Doppler Weather Surveillance Radar (the FAA's and DOD's NEXRAD); the Automated Surface Observing System; the Advanced Weather Interactive Processing System; the Road Weather Information System (RWIS); the National Weather Service (NWS) Weather Forecast Offices; and advanced communication systems and weather satellites.

To reduce weather hazards in aviation, the FAA, NOAA, and other agencies are working with industry through the Aviation Weather Analysis and Forecasting (AWAF) Program. The goal of this program is to improve access to and delivery of more accurate aviation weather information. Among the specific weather topics covered are: in-flight icing; snowfall type and rate; en route turbulence, particularly in clear-air; storm growth, initiation, and decay; ceiling and visibility; windshear events; terrain-induced hazards; and wake vortices.

Based on the integration of intelligent weather and intelligent transportation technologies, the system's technical approach involves the following:

- *Prototype Demonstrations and Pilot Programs:* This activity involves applications of weather technologies in specific modal, geographical, and climatological circumstances, and evaluation of benefits and costs.

- *Data Sharing:* To combine weather data from disparate sources, this effort defines compatible data architectures and exchange standards and coordinates weather information services across agencies and with industry.

- *Meteorology and Data Sources:* This involves the fusion of improved prediction algorithms and atmospheric models with weather information delivery systems. The goal is to apply advances in meteorology to provide weather products with far greater precision and finer resolution.

- *Information Dissemination and Display:* This looks at strategies and technologies for delivering weather information to users. Specific issues include user interfaces for data selection; the display of information specific to particular users' needs; the design of interactive, human-centered displays; and integration of information systems with ITS and air traffic control (ATC).

9. Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure

Vision: A self-sustaining transportation infrastructure that is durable and efficient and that requires fewer human, economic, and environmental resources to operate and maintain.

Goal: Accelerate the comprehensive renewal and advancement of the Nation's aging transportation infrastructure through innovation, particularly advanced materials, construction techniques, and processes.

Participants: RSPA (DOT lead), FAA, FHWA, FRA, FTA, MARAD, USCG. Also DOC (NIST); U.S. Army Corps of Engineers; NSF; Civil Engineering Research Foundation (CERF); state and local DOTs; chemical, automotive, and material manufacturers; infrastructure construction, planning, and management firms; utilities; universities; industry and trade associations.

While advances in infrastructure technology that were unthinkable even a decade ago are on the near horizon, a number of factors combine to discourage innovation. These include the high cost of liability insurance, the multitude of regulations, and industry fragmentation.

This partnership initiative represents the transportation component of the Partnership for the Advancement of Infrastructure and its Renewal (PAIR), an umbrella organization for existing government, private sector, and university infrastructure-related programs. This initiative, called PAIR-T, will foster an unprecedented level of collaboration and synergy on transportation infrastructure research, development, demonstration, testing, evaluation, and technology transfer.

PAIR-T builds on earlier public-private efforts, including the NSTC Committee on Technological Innovation, Construction and Building Subcommittee; HUD's Partnership for Advancing Technologies in Housing; the CERF Construction Materials (CONMAT) effort, a ten-year, $2 billion strategic research and demonstration initiative; and the CERF Innovation Centers. In addition to these efforts, PAIR-T will undertake the following:

- *Critical Technology R&D:* Among other activities, this will develop methods and materials for improving the durability and extending the life of the transportation infrastructure; expand deployment of mobile non-destructive testing (NDT) systems and develop new NDT methods and equipment; adapt information technology to collect and analyze data to model infrastructure condition and performance; improve methods for rapid disaster recovery and response; and develop and evaluate uses of sustainable materials in highway construction.

- *Infrastructure Assessment*: This activity includes assessing infrastructure repair and replacement needs; reviewing existing standards and procurement processes to permit fast-track approval of new technologies; evaluating the use of performance specifications, rather than design specifications, for infrastructure projects; and evaluating the use of life-cycle cost-planning methods.

- *Education and Outreach:* This includes such efforts as publishing guidance on infrastructure performance evaluation and methods; encouraging the adoption of innovative technologies; and developing a national recognition program for states and local governments that use advanced infrastructure technologies.

- *Consensus Building:* This effort will establish industry goals and performance standards; leverage existing federal, state, local, and private initiatives; develop coordinating mechanisms within agencies at all governmental levels; and establish and share databases on infrastructure technology, performance, and assessment.

10. Total Terminal Security

Vision: Passenger and freight transportation terminals that are secure from acts of terrorism and crime. **Goal:** Develop a comprehensive approach to assessing security threats at transportation terminals and to implementing integrated security technologies and procedures tailored to these threats. **Participants:** RSPA (DOT lead), Office of Intelligence and Security, FAA, FHWA, FRA, FTA, ITS Joint Program Office, MARAD, USCG. Also DOD, FBI, INS, U.S. Customs Service, state and local law enforcement agencies, port and airport authorities, transportation service providers.

Recent events in the United States and in other parts of the world have focused considerable attention on the potential occurrence of major incidents of public terrorism. In our own country, such incidents have included the bombings of the World Trade Center in New York City, the Federal Building in Oklahoma City, and the Olympic Park in Atlanta. Throughout the rest of the world there have been bombings and chemical weapon attacks in Japan, Europe, the Middle East, South America, and East Africa. The high level of concern about terrorism is recently reflected in the creation of the Presidential Commission on Critical Infrastructure Protection and the White House Commission on Aviation Safety and Security.

Historically, transportation is among the most visible and frequent targets of terrorist attacks, and recent terrorist incidents have reinforced that observation. Yet another security concern in transportation is cargo theft. Estimates place the losses resulting from such theft at over $13 billion a year.

Assessing the potential threat to transportation facilities and the range of measures that can be taken to guard against them requires the participation and assent of all organizations, both public and private, involved in transportation operations and oversight. This includes numerous federal agencies with transportation, law enforcement, and threat analysis responsibilities, as well as their state and local counterparts; transit and port authorities; and private transportation service providers.

This initiative's focus is on developing and implementing means of improving the overall security of passenger and freight terminals, as well as of the people and cargo transiting those locations. It will address at a minimum the following: the physical security of terminals; the security of vital communication and information systems that service these terminals; and the development and dissemination of information about security incidents, as well as assessments of potential threats, to transportation facilities and operators.

The following research and technology activities are included in this initiative:

- *Transportation Community Awareness and Understanding:* This includes both outreach events on topics related to passenger and freight security, and an ongoing program of system-level vulnerability assessments at major transportation terminals (air, rail, transit, port).

- *Identification of Best Practices:* This activity will assess a number of operational concepts and designs for an integrated security approach, document those that have proven to be the most effective, and identify where further technological or procedural improvements are needed.

- *Identify Key Technologies and Research Needs:* This effort will characterize the security technologies currently available, identify their potential application in an integrated security approach, and determine where further technology development is required.

11. Transportation and Sustainable Communities

> **Vision:** A transportation system that meets the needs for mobility and accessibility while balancing the current and long-term goals of economic growth, environmental quality, and social equity.
>
> **Goals:** Integrate and coordinate existing research agendas to minimize duplication and research gaps, while optimizing support for a sustainable transportation system; develop improved technical tools and models to analyze the impacts of transportation activities on both the natural and the social environment.
>
> **Participants:** FHWA (DOT lead), RSPA, FRA, BTS, FTA, NHTSA. Also U.S. Army Corps of Engineers, DOE, EPA, HHS, HUD, National Parks Service, OMB, Metropolitan Planning Organizations, mayoral offices, environmental advocates, transportation users and service providers, universities, and state and local transportation, environmental, and public health agencies.

Transportation is vital to our economy and our society. It supports economic development through the movement of goods and through access to jobs, services, and other activities. However, as we approach the 21st century, concerns have mounted about transportation's capacity, environmental ramifications, social equity, and public costs.

The negative effects of transportation activities, and the development patterns they support, include: congestion, inefficient land use, unequal access, ecosystem fragmentation, and contribution to greenhouse gases and global warming. Despite widespread recognition of these effects, there is a lack of understanding of how best to balance the sometimes conflicting goals of economic growth, environmental quality, and sustainable communities.

Transportation systems interact with other built, social, and natural systems, and thus have broad impacts on sustainability. This initiative looks at the interrelationships between transportation decisions — policies, investments, and strategies — and development. These relationships produce environmental, social equity, and economic outcomes, sometimes characterized as the "Three E's." Transportation systems can be considered "sustainable" to the extent that they contribute to improved economic opportunity, social equity, public health, and environmental quality.

Federal agencies contribute to sustainable communities through various means. These include: expanding understanding of both the positive and negative consequences of transportation choices; developing better forecasting, planning, and impact assessment tools; continuing technology research; and supporting the development, demonstration, and evaluation of sustainable community transportation initiatives. Under the *Transportation and Community and System Preservation Pilot Program*, $16 million is available in FY 1999 and a projected $25 million annually for FY 2000-2003 to investigate and address the relationship between transportation and both community and system preservation, and to identify private sector initiatives. DOT will work with other federal agencies and participating states, MPOs, and local governments to conduct research, plan, and implement strategies to improve transportation efficiency as well as community and system preservation.

This partnership will further the efforts of federal agencies to work with each other and with other levels of government and the private sector to contribute to sustainability. This initiative encompasses a broad range of research and technology development. These efforts address:

- *Improved Awareness and Understanding of Sustainable Transportation:* This activity will further the dialog on the national policy implications and critical choices relating to transportation and sustainable communities. This dialog involves federal, state, and local agencies; the private sector; environmental and other advocacy groups; and, ultimately, the public. These efforts will contribute to an improved focus for this discussion; identification of alternative policies and their implications; and improved national, state, tribal, and local policies.

- *Behavioral, Social, and Institutional Factors:* This activity seeks to explain the complex relationships among transportation planning, land use, and social equity; and to develop model institutional approaches for cooperative decision making for regional transportation and land use planning.

- *Implementation Issues for Next Generation Vehicles and Fuels:* Addressing the critical role of alternative fuels and vehicles in making transportation more sustainable, this activity involves strategic analysis of: (1) the implications of new vehicles and fuels for the transportation infrastructure and economy as a whole; (2) the different potential evolutionary pathways in moving toward an alternative vehicle/fuel system; and (3) the broader role of petroleum alternatives in achieving sustainability.

- *Information Technology and Sustainable Transportation:* This looks at the implications of information technologies for sustainability. As an example, it would be helpful to determine whether new applications of these technologies to transportation actually result in major changes in travel demand and patterns.

- *Improved Analytical Tools and Indicators:* This activity will develop better tools for understanding the complex relationships between transportation systems and land use and development strategies — including data, performance measures, and a new generation of analytical models.

- *Aviation and Sustainability:* Efforts in this area will examine the environmental impacts of continued growth in aviation, including the implications of introducing "free flight"; policy options for managing this growth, and competitive intermodal options for intercity transportation.

B. Summary Tables

The following six tables summarize the relationship between the eleven NSTC strategic partnership initiatives and the Department of Transportation's broad strategic goals, outcome goals and current R&D programs. In the case of the six new NSTC initiatives, the DOT programs listed represent activities with a similar overall focus that could provide a framework for the new initiative. Additional information on these DOT programs can be found in the *Strategic Plans* of the modal administrations.

Table III-1: Relationship Between Partnership Initiatives and DOT Strategic Goals, Outcome Goals, and R&D Programs (page 1 of 6)

Initiative	Primary DOT Strategic Goal(s)	DOT Outcome Goals	DOT R&D Programs
Accessibility for Aging and Transportation - Disadvantaged Populations	*Mobility:* Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offer flexibility of service.	• Increase access to the transportation system for the movement of all people and freight.	• Advanced Public Transportation Systems (FTA) • Advanced Rural Transportation Systems (FHWA, FTA) • Autonomous Dial-a-Ride Transportation (FTA) • ITS Crash Avoidance Research (NHTSA) • Metropolitan and Rural Policy Development (FTA) • National Advanced Driving Simulator (NHTSA) • Rural and Specialized Transportation (FTA) • Rural Transit Assistance Program (FTA) • Safe Communities Program (NHTSA) • Transit Services and Management Innovation (FTA)
Aviation Safety Research Alliance	*Safety:* Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage.	• Reduce the number of transportation-related deaths. • Reduce the number and severity of transportation-related injuries. • Reduce the rate of transportation-related fatalities. • Reduce the rate and severity of transportation-related injuries.	• Aging Aircraft (FAA) • Aircraft Icing (FAA) • Aviation Human Factors (FAA) • Aviation Performance Measuring System (FAA, NASA) • Aviation Safety Program (FAA, NASA) • Aviation Safety Reporting System (FAA, NASA) • Aviation Weather Research (FAA) • Global Analysis Information System (FAA, NASA) • Wake Vortex (FAA) • Wind Shear (FAA)

Table III-1 (cont.): Relationship Between Partnership Initiatives and DOT Strategic Goals, Outcome Goals, and R&D Programs (page 2 of 6)

Initiative	Primary DOT Strategic Goal(s)	DOT Outcome Goals	DOT R&D Programs
Enhanced Goods and Freight Movement at Domestic and International Gateways	*Economic Growth and Trade:* Advance America's economic growth and competitiveness domestically and internationally through efficient and flexible transportation. *Mobility:* Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offers flexibility of service.	• Reduce the real economic cost of transportation. • Reduce average delivery time for people, goods, and services. • Improve reliability of the delivery of people, goods, and services. • Increase economic growth and trade through wise, cost-effective transportation investments. • Increase intermodal physical, information, and service connectivity. • Increase access to the transportation system for the movement of all people and freight.	• Commercial Vehicle Operations (FHWA) • Traffic Management and Traveler Information (FHWA) • National Corridor Planning and Development Program (FHWA) • Coordinated Border Infrastructure Program (FHWA) • Industry Competitiveness (MARAD) • Intermodal Development (MARAD)
Enhanced Transportation Weather Services	*Safety:* Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage.	• Reduce the number of transportation-related deaths. • Reduce the number and severity of transportation-related injuries. • Reduce the number of reportable transportation incidents and their related economic costs.	• Aviation Weather Research (FAA) • Crash Avoidance Research (NHTSA) • Intelligent Weather Systems (FRA) • National Advanced Driving Simulator (NADS) • Strategic Highway Research Program (FHWA) • Rural Weather Information Service (FHWA)

Table III-1 (cont.): Relationship Between Partnership Initiatives and DOT Strategic Goals, Outcome Goals, and R&D Programs (page 3 of 6)

Initiative	Primary DOT Strategic Goal(s)	DOT Outcome Goals	DOT R&D Programs
Intelligent Vehicle Initiative	*Safety:* Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage. *Mobility:* Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offers flexibility of service.	• Reduce the number of transportation-related deaths. • Reduce the number and severity of transportation-related injuries. • Reduce the number of reportable transportation incidents and their related economic costs.	• Advanced Motor Vehicle Safety (NHTSA) • Intelligent Vehicle Initiative (FHWA, FTA, NHTSA) • Motor Carrier Research (FHWA) • Advanced Public Transportation Systems (FTA)
Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure	*Mobility:* Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offers flexibility of service. *Safety:* Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage.	• Improve the structural integrity of the transportation system. • Balance new physical capacity with the operational efficiency of the nation's transportation infrastructure. • Provide preventive measures and expeditious response to natural and man-made disasters.	• Applied Research and Technology (FHWA) • Local Technical Assistance Program (FHWA) • Pavement Research (FHWA) • Seismic Research and Development Program (FHWA) • State Planning and Research Program (FHWA) • Strategic Highway Research Program (FHWA) • Structures Research Program (FHWA) • Technology Assessment and Deployment (FHWA) • Track, Structures, and Train Control (FRA)

Table III-1 (cont.): Relationship Between Partnership Initiatives and DOT Strategic Goals, Outcome Goals, and R&D Programs (page 4 of 6)

Initiative	Primary DOT Strategic Goal(s)	DOT Outcome Goals	DOT R&D Programs
National Intelligent Transportation Infrastructure	*Safety:* Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage. *Mobility:* Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offers flexibility of service.	• Reduce the number of transportation-related deaths. • Reduce the number and severity of transportation-related injuries. • Balance new physical capacity with the operational efficiency of the transportation infrastructure. • Increase intermodal physical, information, and service connectivity.	• ITS Architecture and Standards (FHWA, FTA) • ITS Deployment Incentive Program (FHWA) • ITS Mainstreaming (FHWA, FTA) • ITS Program Support (FHWA, NHTSA) • Nationwide Differential GPS (FHWA, FRA, USCG)
Next Generation Global Air Transportation	*Mobility:* Shape America's future by ensuring a transportation system that is accessible, integrated, efficient, and offers flexibility of service. *Economic Growth and Trade:* Advance America's economic growth and competitiveness domestically and internationally through efficient and flexible transportation.	• Balance new physical capacity with the operational efficiency of the nation's transportation infrastructure. • Increase access to the transportation system for the movement of all people and freight. • Reduce the real economic cost of transportation. • Increase economic growth and trade through wise, cost-effective transportation investments.	Joint FAA/NASA projects: • ATM Advanced Concept Studies • Human Factors • System Performance Assessment • ATM Methods and Analysis • Application of Aircraft Capabilities • Collaborative Decision Making • Airport Surface Management • Tower/Airfield Functionality • Low/Zero Visibility Tower • Final Approach Spacing Tool • Dynamic Final Approach Spacing • Parallel Runway Spacing Reduction • Hazardous Weather Avoidance • CTAS Adaptation/Implementation • Collaborative Arrival Planning • FMS/RNAV Routing • Arrival/Departure Management • Capabilities to Support Free Flight • Adv. Oceanic Automation System • Separation Methods & Standards

Table III-1 (cont.): Relationship Between Partnership Initiatives and DOT Strategic Goals, Outcome Goals, and R&D Programs (page 5 of 6)

Initiative	Primary DOT Strategic Goal(s)	DOT Outcome Goals	DOT R&D Programs
Next Generation Surface and Marine Transportation Vehicles	*Human and Natural Environment:* Protect and enhance communities and the natural environment affected by transportation. *Economic Growth and Trade:* Advance America's economic growth and competitiveness domestically and internationally through efficient and flexible transportation.	• Reduce the amount of transportation-related pollutants and greenhouse gases released into the environment. • Improve the U.S. international competitive position by facilitating the export of domestic transportation goods and services.	• Advanced Bus Propulsion Systems (FTA) • Advanced Vehicle Program (RSPA, FHWA–proposed) • Demonstration of Fuel Cell Propulsion for Ships (MARAD, RSPA, USCG, DARPA, DOE, NOAA, US Navy) • Heavy Vehicles (NHTSA) • Motor Carrier Research (FHWA) • New Bus Vehicles and Infrastructure (FTA) • Next Generation High-Speed Rail (FRA) • Partnership for a New Generation of Vehicles (NHTSA) • Safety Systems (NHTSA) • Shipyard Revitalization (MARAD) • Support for Interagency Ship Structure Committee (USCG, MARAD)
Total Terminal Security	*National Security:* Advance the nation's vital security interests in support of national strategies such as the National Security Strategy and National Drug Control Strategy by ensuring that the transportation system is secure and available for defense mobility and that our borders are safe from illegal intrusion.	• Reduce the vulnerability and consequences of intentional harm to the transportation system and its users.	• Aircraft Hardening (FAA) • Airport Security Technology Integration (FAA) • Aviation Security Human Factors (FAA) • Explosives and Weapons Detection (FAA) • Safety and Security (FTA)

Table III-1 (cont.): Relationship Between Partnership Initiatives and DOT Strategic Goals, Outcome Goals, and R&D Programs (page 6 of 6)

Initiative	Primary DOT Strategic Goal(s)	DOT Outcome Goals	DOT R&D Programs
Transportation and Sustainable Communities	*Human and Natural Environment:* Protect and enhance communities and the natural environment affected by transportation.	• Improve the sustainability and livability of communities through investments in transportation facilities. • Reduce the amount of transportation-related pollutants and greenhouse gases released into the environment. • Reduce the adverse effects of siting, construction, and operation of transportation facilities on the natural environment and communities, particularly disadvantaged communities.	• Environmental Justice (FAA, FHWA, FRA, FTA) • Environmental Research (FHWA) • Livable Communities (FTA) • Metropolitan and Rural Policy Development (FTA) • Planning and Project Development (FTA) • Policy Research (FHWA) • Right-of-Way Research (FHWA) • Rural and Specialized Transportation (FTA) • Safe Communities Program (NHTSA) • Transit Services Management Innovation (FTA) • Transportation Planning Research (FHWA) • Travel Model Improvement Program (FHWA) • Transportation and Community and System Preservation Pilot Program (FHWA)

C. DOT Technology Transfer and Other Programs Supporting Partnership Initiatives

Since its formation, the Department has engaged in cooperative research with elements of the transportation community. As a result, a variety of ongoing efforts are directly supportive of the newly-articulated integrated NSTC initiatives. To illustrate those linkages to the NSTC's S&T strategy, the existing partnership activities are presented and discussed in the context of the 11 partnership focus areas defined by the NSTC (as described in section A of this chapter). *Table III-2* depicts some of these DOT programs and the NSTC initiatives with which they are associated.

1. Aviation Safety

Several federal partnership initiatives exist that address aviation safety. The FAA, along with the FHWA and FRA, is undertaking performance modeling of hours-of service alternatives. The research will assess the impacts of a variety of wake-sleep schedules on operator fatigue and loss of alertness. The FAA also is working with other federal agencies, private industry, and academia, to study factors affecting airport security equipment operators' interaction with new airport security screening systems. Finally, an aviation safety research partnership between the FAA, NASA, DOD and the aviation industry is underway. The goals of this project are to develop innovative technologies and products to reduce human-caused accidents; eliminate accidents due to weather; and lower accidents due to malfunctions of critical systems.

2. Next Generation Global Air Transportation

Several important partnerships are underway that will enhance air transportation, and enable the full adoption of next-generation aircraft. The FAA and the Boeing Company have joined in a Cooperative Research And Development Agreement (CRADA) to launch a $21 million research effort that will address the increased runway pavement impact of the next generation of large civil transport aircraft, such as the Boeing 777. As part of this agreement, a test machine will help identify new procedures required to design airport pavements to meet the requirements of these new aircraft. Supporting this research effort are the Army Corps of Engineers and Daniel, Mann, Johnson, and Mendenhall/Cornell Joint Venture. The test machine is expected to be operational in April 1999.

To better understand the behavior of airport pavements under operational conditions, the FAA initiated the Airport Pavement Instrumentation Project in 1992 at the new Denver International Airport (which was under construction at the time). Through an interagency agreement with the Army Corps of Engineers' Waterway Experiment Station, various sensors were embedded in sections of one runway. Pavement condition data from these sensors are collected and stored in an FAA database and are accessible through an FAA (AAR-410) web server.

Table III-2: NSTC Partnership Initiatives and Supportive DOT Cooperative Projects

NSTC Partnership Initiative	Related DOT Cooperative Projects
1. Accessibility for Aged and Transportation- Disadvantaged	• Alternative Mobility Options (FTA, NHTSA) • Bus Rapid Transit (FTA, transit agencies) • Transit Connectivity to Airports (FTA, FAA, transit agencies, aviation industry)
2. Aviation Safety Research Alliance	• Aviation Safety Research Partnership (FAA, NASA. DOD, industry)
3. Enhanced Goods and Freight Movement at Gateways	• Positive Train Control projects (FRA, railroads, state DOTs) • Cargo Handling Cooperative Program (MARAD, shippers) • Ship Operations Cooperative Program (MARAD, USCG, shippers)
4. Enhanced Transportation Weather Services	• FORETELL (FHWA, Iowa DOT, industry)
5. Intelligent Vehicle Initiative	• Partnership for a New Generation of Vehicles (FHWA, FRA, FTA, NHTSA, DOE, EPA)
6. Monitoring, Maintenance and Rapid Renewal of Physical Infrastructure	• Highway Innovative Technology Evaluation Center (FHWA, CERF) • National Technology Deployment Initiative, Priority Technologies Program (FHWA, state & local DOTs)
7. National Intelligent Transportation Infrastructure	• ITS Deployment Incentives Program (FHWA, FTA, state & local DOTs) • Operation Respond (FHWA, FRA, RSPA, state & local agencies, freight carriers)
8. Next Generation Global Air Transportation	• Runway Pavement Test machine (FAA, US Army Corps of Engineers, Boeing, DMJM, Cornell) • Airport Pavement Improvement Project (FAA, USACE)
9. Next Generation Motor Vehicles, Locomotives, and Ships	• Demonstration of Fuel Cell Propulsion for Ships (MARAD, RSPA, USCG, DARPA, DOE, NOAA, US Navy) • Demonstration of Universal Electric Subsystems (FTA, DARPA) • Very Large, High Speed, Composite Ship (MARAD, DOD, industry)
10. Total Terminal Security	• Best Practices in Cargo Security (DOT, National Cargo Security Council)
11. Transportation and Sustainable Communities	• Transportation Alternatives and Air Quality Impacts (FHWA, FTA, EPA) • Improved Forecasting Effects of Transportation Improvements (DOT, EPA)

The FAA and NASA coordinate closely in a joint program designed to accomplish several goals related to air traffic control. This effort evaluates system and user operational flexibility and productivity in an integrated air-ground environment, and investigates human-centered aiding systems for flight deck and air traffic control operations. It is also developing human factors information to improve training and operational efficiency, such as improved communication exchanges and collaborative decision-making between pilots, air traffic controllers and airline dispatchers.

The FAA and NASA are exploring ways to mitigate the adverse environmental impacts of civil aviation. This research will cover aircraft noise reduction (e.g., high lift devices and methods to reduce airframe-generated noise), reducing harmful engine emissions (e.g., nitrous oxides), and evaluating the impact of current subsonic aircraft operations on the ozone layer and global climate change.

3. National Intelligent Transportation Infrastructure

The FHWA and FTA are involved in the Model Deployment Initiative (MDI). This large-scale cooperative project was developed to showcase the deployment of ITS across the country. Four model deployment metropolitan areas (Phoenix, Seattle, San Antonio, and New York) were chosen to illustrate how technology can improve transportation in metropolitan areas. FHWA and FTA also are cooperating on the ITS Priority Corridors Program. The program was designed to evaluate and demonstrate the benefits of ITS technologies and integrate ITS within a region. Four corridors (Virginia to Maine, Houston, Gary-Chicago-Milwaukee, and Southern California) were chosen as the test areas.

The key to achieving widespread compatibility among ITS technologies and programs is the development of industry-wide, non-proprietary standards. A number of federal agencies, FHWA, FTA, FRA, and NHTSA are cooperating on the ITS Standards project. This effort is designed to accelerate the development of ITS standards, and is multi-modal in nature.

Safety is an important aspect of intelligent infrastructure. ITS technologies provide excellent opportunities to enhance the safety of transportation networks by increasing the speed and efficiency of emergency response. The FHWA, FRA, and RSPA are partnering on Operation Respond, which will develop direct multi-modal communications linkages between 911 operators, emergency responders, and freight carriers (railroads and commercial motor vehicles) during the initial response to Hazardous Materials incidents. The Operation Respond Emergency Information System (OREIS) is a Windows-based application which provides direct access to connect police and fire dispatch centers with railroad and motor carrier data bases.

USCG, FRA and FHWA are working with the U.S. Air Force and the U.S. Army Corps of Engineers to arrange the transfer of decommissioned Ground Wave Emergency

Network (GWEN) sites for use in the Nationwide Differential GPS Network. They are also working with other federal agencies – including Agriculture, Commerce, Energy, Justice and Treasury – to insure that their requirements are being met by this new network.

4. Next Generation Surface and Marine Transportation Vehicles

Hybrid-electric and electric transit vehicles provide an opportunity for the transit industry to reduce urban bus emissions and to improve fuel efficiency. The FTA's Advanced Bus Propulsion Systems Program will complete the Demonstration of Universal Electric Transportation Subsystems (DUETS) program that was initiated with DARPA funding and managed by FTA. FTA will continue to work with the Calstart consortium on the development of a number of advanced technologies and transit vehicles, including the development of an ultra-capacitor energy storage system for the Advanced Technology Transit Bus (ATTB). The testing, demonstration and evaluation of a zinc-air battery propulsion system for a transit bus will also be conducted. In addition, FTA will continue to provide technical assistance in advanced transit technology alternatives and transportation planning to the National Park Service, in support of the joint memorandum of understanding between the DOT and the Department of the Interior.

FRA is partnering with the Defense Advanced Research Projects Agency (DARPA), the railroad industry association, and a locomotive manufacturer to develop a high-speed, light-weight turbine-powered locomotive for intercity corridor operations.

FTA, in conjunction with the American Public Transit Association (APTA), has had preliminary discussions with EPA concerning the emissions certification of hybrid-electric transit buses.

MARAD is partnering with DOD and industry to promote the development of very large, high speed (150 knots) ships with hulls made completely of composite materials that can also have low draft capabilities to enable cargo deliveries in shallow water facilities.

5. Intelligent Vehicle Initiative

Although direct linkages between existing partnership initiatives and technology sharing programs within DOT Administrations and the Intelligent Vehicle Initiative have not yet been established, there are some programs where associations do exist. Among these are programs where evaluations of forward-looking radars, blind spot sensors, and color video sensing are being conducted. The program includes evaluations of: ITS rural applications, such as weather and safety advisories and mobility management; prototype public transit demonstration systems, such as passenger smart cards, transit information, and fleet management; and prototype collision avoidance systems. The evaluations will cover the safety aspects of automatic collision notification, intelligent cruise control, and the automatic on-the-road inspection of heavy trucks. In another related area, NHTSA is evaluating the potential benefits of ITS-based collision-avoidance systems and is assessing the safety impacts of new ITS products.

6. Accessibility for Aging and Transportation-Disadvantaged Populations

In addition to the regional paratransit program mentioned previously, the Department is involved in several important projects that will enhance the mobility of aging and transportation-disadvantaged populations. In Portland, Maine, the Independent Transportation Network (ITN) service demonstration program focuses on improving transportation for the elderly. Through the 'Safe Mobility for Life' program, NHTSA is working with other agencies and the private sector is developing and evaluating material designed to assist the elderly to enjoy the benefits of mobility for as long as possible. Activities include developing a model system for screening and evaluating older drivers that incorporates mobility counseling, and developing materials to assist the elderly in deciding when and whether to curtail their driving and to explain mobility alternatives. The Advanced Rural Transportation Systems program, operated jointly by FHWA and the FTA, supports new, innovative transit services that can improve mobility for 30 million rural elderly, low-income, and disabled residents.

Although not directly related to accessibility, several additional programs will improve the overall quality and effectiveness of transit services. For example, the Bus Rapid Transit program is a technology transfer effort that involves coordinated investments in infrastructure, equipment, operational improvements, urban design enhancements, and new ITS, traffic engineering, and vehicle technologies. The goal is to increase vehicle speed and ridership while reducing travel time, operating costs, and emissions. The FTA, in partnership with local entities, will demonstrate the concept of Bus Rapid Transit in several cities, and will then disseminate findings so transit systems across the country can adopt them. The Transportation Equity Act for the 21st Century (TEA-21) created the 'Access to Jobs' and 'Reverse Commute' programs. Administered by the FTA, these programs provide grants to local governments and non-profit agencies to develop and deploy new technologies, establish transit voucher programs, and assist employers provide transportation to their employees.

Intermodal connectivity is important for enhancing the mobility of transit-dependent populations, including providing access to employment. The FTA, in partnership with the FAA, the air transportation industry, and state and local officials, is addressing transit connectivity to airports. This work includes studying examples from Europe and Asia of cities that provide exceptional air-transit connectivity.

In the area of technology sharing, the FTA will embark on a more vigorous program of technology sharing in assisting the transit industry to keep abreast of the latest technological innovations in systems, management programs, equipment and infrastructure. NHTSA is cooperating with state and local agencies in helping people who are no longer able to drive to maintain their mobility by using new technologies and information systems.

7. Enhanced Goods and Freight Movement

FRA is working with railroads and state DOTs in the development and demonstration of Positive Train Control (PTC) systems to enhance the movement of goods and freight in addition to intercity and commuter passengers. PTC should yield important safety and efficiency benefits.

Marine freight movement is enhanced by the Marine Terminal Automated Management System. This is a pioneering effort by the MARAD in cooperation with the port industry to develop an automated terminal control system that would enhance the accuracy and timeliness of information related to the terminal operators. It is designed to provide an on-line inventory of containers, cargo, and chassis, and their respective locations. This inventory is updated by transactions entered at the five major operating nodes within a terminal: gate, yard office, window office, container control, and vessel planning.

The MARAD and the U.S. DOT, along with several domestic shipping companies, are partnering on the Cargo Handling Cooperative Program (CHCP). The CHCP is designed to foster research and technology development by U.S.-flag carriers. An executive committee comprising representatives from all the partners administers the program. The program calls for improvements in cargo handling relating to the identification and prototyping of new technologies for container-chassis mating, as well as testing new technologies related to hand-held computers, electronic seals, overweight containers, and container stowage planning. The MARAD and private participants fund the CHCP.

The Ship Operations Cooperative Program (SOCP) was formed in 1993 to enable multiple organizations to work together on projects which were not economically feasible on an individual basis, but had high payoff potential. Work is performed using annual membership fees, as well as the personnel resources of the members. The membership has grown steadily from five members in 1993 to the current level of thirty members, and growth is expected to continue in the foreseeable future. The primary focus is on training of shipboard crews to meet international requirements of the Standards of Training, Certification, and Watchkeeping convention. The Year 2000 computer problem, as well as safety incident reporting and reliability data collection, are also major activities of the program.

Long-term partnership initiatives in the area of enhanced goods and freight movement include the development of a national intermodal freight movement investment strategy. Existing technologies for cargo tracking, just-in-time inventory management, warehousing and distribution, and freight records management were developed and have evolved as independent, mode-specific systems. These systems no longer are adequate to meet the demands of the increasingly multi-modal freight industry. The partnership initiative between FHWA and other agencies will develop a strategy for intermodal data exchange. This strategy will offer many important opportunities to increase the efficiency and capacity of the nation's freight distribution systems. Better management of NHS roadways by state and local governments will provide better prediction of trip travel times, which will greatly enhance just-in-time delivery management.

8. Enhanced Transportation Weather Services

Several partnerships are underway to enhance transportation-related weather forecasting and information dissemination. The FAA, in partnership with NASA is improving aviation weather analysis and forecasting capabilities by developing algorithms for the next generation weather radar and other new radars, as well as by developing an airborne humidity sensor.

FHWA is developing Weather Information Systems for surface transportation operators and travelers. Among these items are an inexpensive, improved visibility sensor for highway fog situations, a rolling wave deflectometer and a laser-based system to measure road surface texture and other features, and an improved ice sensor for highway use. This research into weather could be joined with the efforts of other agencies. For example, both FHWA and the FAA are seeking to integrate multiple air and ground sensors and systems for improved large area weather forecasting.

9. Monitoring, Maintenance, and Rapid Renewal

Numerous partnerships involving a wide range of federal agencies and other parties are underway in the areas of transportation infrastructure monitoring, maintenance, and rapid renewal. One very significant project is the Strategic Highway Research Program (SHRP). The SHRP was designed to improve the safety, durability, and performance of the Nation's aging highways. The five-year, $150 million research program initially was funded by Congress in 1987 from the FHWA Highway Trust Fund, and managed by the TRB in cooperation with the AASHTO. The SHRP research emphasized developing innovative technology products in four program areas: asphalt, concrete and structures, pavement performance, and highway operations. The research was conducted by state and local transportation authorities, academia, and industry. The SHRP was very successful, producing over 130 new technology products and services by 1992. More than 290 reports were published by the TRB under the SHRP, and a SHRP Products Catalog describing over 100 products resulting from the program was widely disseminated.

The benefits of the SHRP currently are being realized through systematic implementation. Section 6001 of the ISTEA set aside $108 million over six years for this purpose. Products of this long-term effort were being developed, modularized, and packaged under the guidance of a Coordination Group (which includes FHWA field organizations, industry associations, TRB, and users) and Technical Working Groups for Asphalt, Concrete and Structures, Highway Operations, and Long-Term Pavement Performance.

Another major partnership initiative is the Highway Innovative Technology Evaluation Center (HITEC). The FHWA established HITEC in 1992 under a four-year cooperative agreement with the Civil Engineering Research Foundation (CERF). The HITEC facilitates the evaluation, demonstration and deployment of innovative materials, products, services, systems and technologies for transportation infrastructure applications. To speed up the process of implementing innovations, the HITEC convenes an expert review and evaluation panel for each applicant. Each panel comprises interested public, private, and academic stakeholders, including state and local highway officials and highway users. In many cases, these users become 'change agents' themselves and ensure a greater probability that successful applications will be deployed.

The HITEC is a model partnership for successful and timely technology deployment, based on an initial customer survey that identified barriers to innovation in highway materials and construction technologies and tools. In its first year, more than 20 products were submitted to HITEC for evaluation and endorsement. The costs of field testing typically range from about $100,000 to $1 million; application fees (about $5,000 for initial screening and about $20,000 for an evaluation plan) cover part of these costs. The FHWA contributed funds from the ISTEA Section 6005 technology application set-aside resources.

HITEC evaluations have included advanced bridge materials (composite bridge decks), repair (polyester concrete structure repair) and quick assembly (pre-tensioned concrete modular bridge) technologies; a gyratory test machine; a liquid bonding compound for asphalt materials that can speed up pothole repair and improve patching; pavement marking compounds; weigh-in-motion sensors; a Sight and Sound Screen to mitigate highway noise; and rapid in-situ testing methods for water/cement ratio in fresh concrete, an important performance indicator that guides acceptance tests for all structural development and rehabilitation projects.

Other notable HITEC successes include: evaluation of the composite column wrap for seismic bridge reinforcement, building upon tests at the University of California at San Diego; comprehensive evaluation of seismic isolation and energy dissipation technology options; the SNOWFREE heated pavement using embedded graphite fibers; a bridge retrofit system; a marine composite plastic piling impervious to corrosion; and the ALLSIGN Stop sign made of recyclable plastic and with improved reflectivity and night visibility. To date, more than sixty evaluations of innovative infrastructure technologies are in process; many of these involve advanced materials. Each completed evaluation results in a brief Product Evaluation Bulletin, followed by a more complete Evaluation Report.

Following on the success of the HITEC, the CERF recently established additional Technology Evaluation Centers; the CEITEC, to evaluate public works innovations; and EvTEC, the Environmental Technology Evaluation Center.

The Center for Advanced Cement-based Materials (ACBM), located at Northwestern University, is funded by the NSF, NIST, FHWA, and companies in the concrete and ceramics industries. Ongoing projects include non-destructive infrastructure test and evaluation (NDT/NDE), advanced coatings to prevent corrosion, and a high-strength weldable steel.

Important work is occurring in the area of aviation-related infrastructure. For example, in 1995, the FAA established a National Center of Excellence in Pavement Research at the University of Illinois, in conjunction with Northwestern University, to conduct basic research on advanced airport runway pavement materials, monitoring, modeling, and renewal.

The FRA is involved in a number of partnerships related to rail infrastructure monitoring and renewal. The agency developed the Gage Restraint Measurement System (GRMS) to measure track gage strength capacity. Under this cooperative program, the FRA provides the GRMS and covers the setup and tear down expenses of the equipment. The participating railroad pays for the actual track testing. FRA is also cooperating with the American Association of Railroads and the National Science Foundation to assess bridge failure risks.

Load rating of public highway bridges is an important aspect of infrastructure management. The FHWA is working with the Department of the Army, Military Traffic Management Command, Transportation Engineering Agency, and the New Mexico Department of Transportation to develop a system to load rate most of the typical U.S. bridge types for the Army's 1,000-ton Heavy Equipment Transportation System (HETS). The program will be used to select routes for the HETS in case of national emergency or in cases where other non-emergency relocation of HETS is necessary.

10. Total Terminal Security

Concerns about personal safety may deter some people from using public transportation. These concerns have been heightened by the March 1995 sarin attack on a Tokyo subway. The tunnel network of a subway system, with its moving trains and many ventilation shafts, could distribute a chemical or biological agent to an entire city. Transit authorities need an integrated approach to dealing with the possibility of a Chemical/Biological attack on a U.S. subway system. This approach should include the development of new technology and advanced emergency response strategies. DOT is working with the DOE, the DOD, and FEMA to develop such an approach.

11. Transportation and Sustainable Communities

Numerous partnerships are currently underway to address the role of transportation in fostering sustainable urban development. One important aspect involves educating the public about the links between transportation and environmental protection. To this end, the DOT and EPA are developing an education campaign to inform the public of their transportation choices and the consequences of those choices. In a complementary effort, FHWA, FTA and EPA will present transportation and air quality issues directly to the public through outreach and education strategies that highlight relationships between transportation alternatives and air quality impacts. Through its Transportation Partners program, the EPA is working with non-governmental organizations, citizens groups, local governments, and businesses to develop innovative transportation solutions in communities across the country. Also, FHWA is partnering with the Institute of Traffic Engineering (ITE) to investigate advanced traffic calming techniques.

In the area of renewable transportation fuels, DOE and EPA are partnering on major research to reduce the cost of biodiesel production. This research focuses on identifying high oil content crops, and on ways of lowering the costs of producing these crops and refining their oils for use in diesel engines.

The DOT and EPA are cooperating on a program to improve the ability to forecast the effects of transportation improvements on air quality, energy, land development, and congestion.

D. New Proposed Partnership Initiatives

Two new partnership initiatives have been recently proposed. The first, by the United States Coast Guard, requested that the NSTC consider an additional category of partnership initiatives to the R&D Plan. This initiative, called the Marine Safety Research Alliance, partners the Coast Guard with MARAD and the marine industry. The partnership's stated goal is to reduce maritime deaths and injuries by 20%. Within the Alliance are some twelve existing and planned projects. These include development of a national "Near-Miss" reporting system to track incidents that almost result in vessel collisions; human factors in casualty investigations to identify human-related causes of fatal accidents; measurement and assessment of effects of human-related factors (i.e., sleep, watch keeping schedules) on crew alertness; improved crew safety on offshore supply vessels; and shipboard fatigue countermeasures analysis.

The second initiative, recently announced by Vice President Al Gore, Transportation Secretary Rodney E. Slater and FAA Administrator Jane F. Garvey, is called "Safer Skies". This effort has adopted a priority safety agenda designed to reduce fatal accidents by a factor of five. The agenda will use of the latest technology to help analyze U.S. and global aviation data to find the root causes of accidents and determine the best actions to break the chain of events that lead to accidents.

"Safer Skies" will use partnerships between the FAA, NASA, and the aviation industry, including flight crews, operators, and manufacturers. It will expand aircraft engine inspections and improve pilots' warning and detection systems. The agenda's focus will be in three areas:

1. Controlled flight into terrain (CFIT), loss of control, uncontained engine failures, runway incursions, approach and landing, and weather for commercial aviation;

2. Pilot decision-making, loss of control, weather, CFIT, survivability and runway incursions for general aviation; and

3. Cabin safety dealing with passenger seat belt use, carry-on baggage, child restraints, and passenger interference issues.

CHAPTER IV: Enabling Research

The NSTC enabling research areas previously mentioned in Chapter II include activities that meet the following criteria:

- Support long-term national transportation goals;
- Have benefits that are too diverse for a single company to recover and profit from its investment;
- Are associated with cost or risk that is beyond the capacity of any individual company; and
- Generates benefits that will begin to be realized too far in the future to pass the threshold of shorter-term private investment criteria.

The *S&T Strategy* identifies six enabling research areas that provide a focus for committing resources. These areas are also consistent with the principles of the President's Committee of Advisors on Science and Technology, as well as with the U. S. Department of Transportation Strategic Plan 1997-2002. The Department's Research and Technology Management Strategy specifically focuses on Enabling Research that will "foster innovative and cutting-edge research", building upon efforts conducted by "other federal agencies, institutes of higher learning, and the private sector." [1]

These six enabling research areas are:

1) Human Performance and Behavior,
2) Advanced Materials and Structures,
3) Computer, Information, and Communication Systems,
4) Energy, Propulsion, and Environment,
5) Sensing and Measurement, and
6) Analysis, Modeling, Design, and Construction Tools.

Each of these six categories includes both near-term (5 years or less) and long-term (more than five years) enabling technology programs being managed by DOT Administrations, as well as those cooperatively conducted with other federal agencies, private industry, and academia. The cooperative programs include some descriptions of efforts that would occur in the later stages of the partnership initiatives discussed in Chapter III.

[1] *US DOT Strategic Plan 1997-2002,* p. 64.

The long-term programs are recommendations on areas where some of the enabling technologies can be used to develop advanced improvements to transportation. Individual programs within one DOT Administration that cover similar technology topics are grouped together to identify synergies that may arise in the long-term efforts.

Because of their more immediate objectives, almost 90% of the near term programs address research by a single DOT modal agency. Almost one-half of the long-term programs, however, are multi-modal in nature.

A. Human Performance and Behavior

Human factors in DOT involves the understanding of how the people involved in operating and using transportation systems (e.g., vehicle operators, air traffic controllers, and associated maintenance, inspection, and search and rescue personnel) perceive, process, and act upon information in "real life" situations.

Human factors issues in transportation can be broadly grouped into three areas: first, user *fatigue*; second, deteriorated *human performance*; and third, *human-machine interactions* that are inflexible, prone to human error, or non-productive between system operators and users. *Human-machine interactions* are a concern when major changes to the system are implemented (e.g., automation) or miscommunications occur that could lead to accidents.

DOT programs on fatigue and performance emphasize these three areas. For example, the programs investigate the concern that a vehicle operator generally does not recognize fatigue until at least an hour after its actual onset. They address workload stresses and they seek to incorporate recent advances in simulation and data acquisition capabilities that now permit the analysis of human performance in real time.

DOT human factors programs have been strongly influenced by the substantial and continued federal investments in the ITS program and the FAA's major improvements to the National Airspace System. The FAA's improvements include basic conceptual changes from today's ground-based air traffic management to the cooperative air-ground "free flight" system, in which pilots, air traffic controllers and airline operations center personnel collaborate in decision making.

There are a number of near term and long term DOT research programs in the Human Performance and Behavior category of Enabling Research. Because of their higher number, the near term programs in this category and the other five Enabling Research areas have been grouped within specific broad topics.

Near Term

1. *Fatigue*

The FRA is conducting research on the effects of work schedules on fatigue (lack of alertness) and stress on locomotive engineers (including high-speed train operators), dispatchers, and other railroad personnel. The effects of these factors on performance and safety will be evaluated. The use of napping and vigilance monitoring are areas of FRA research to evaluate mitigation measures. A related question concerns the amelioration of such fatigue and stress by adjustments in work schedules, crew calling procedures, high service requirements and the work environment.

NHTSA in conjunction with the FHWA's Office of Motor Carriers, is developing and testing an on-board truck driver alertness measurement tool. Motor Carriers is also conducting research on the relationship between the hours-of-service requirements and fatigue of commercial vehicle drivers.

The U. S. Coast Guard is conducting research on fatigue countermeasures for ships crews on deep-draft, towing, and cutter vessels.

The FAA is conducting fatigue-related research to assess the effects of duty times, shift rotations, and napping on performance, and is assessing the effectiveness of various fatigue countermeasures.

2. *Human Performance*

NHTSA is constructing the National Advanced Driving Simulator (NADS), a large and sophisticated automobile simulator to test many different types of driver performance. They will undertake driver/vehicle integration research to evaluate advanced crash avoidance technologies and their potential for preventing crashes and consumer acceptance of such technologies when NADS becomes operational.

NHTSA is performing crashworthiness research that seeks to help drivers avoid crashes or decrease crash severity by improving their performance. They are also developing assessment and rehabilitation tools to enable older people to drive longer.

Railroad operator performance is affected by many factors. The FRA is conducting research on locomotive engineer, dispatcher, and yard and terminal operator performance to determine the safety impacts of fatigue and stress. In addition, as part of the grade crossing safety program, FRA is investigating automobile driver behavior to determine why drivers go around crossing gates when they are down and the lights are flashing.

The FAA is studying improved flight deck human engineering and the mitigation of environmental factors affecting the performance of flight crew, maintenance, and inspection personnel. The FAA is also studying shared information display and interface designs for air traffic controller and maintenance workstations. They are implementing line-oriented flight training for airline pilots and advanced training of general aviation pilots, and studying the human factors of air-to-air communications via digital data links.

3. Human-Machine Interactions

NHTSA is developing a portable data acquisition tool to understand driver-vehicle interactions. The device will unobtrusively monitor driver behavior and vehicle response in circumstances such as reduced road visibility, drowsiness, or increased disabilities with age.

The U. S. Coast Guard is investigating enhancements to communications and coordination between marine pilots and the vessel bridge teams.

The FAA is performing research to improve safety and productivity through a reduction of system and human errors when the major changes to air traffic services occur as "free flight" is implemented in the future.

The FAA is researching the characteristics required for operators to interact with new airport security screening systems that result from emerging technologies such as x-ray tomography, the identification of predetermined planes of solid objects while blurring the images of other planes. This program, which involves a collaboration with other federal agencies, industry and academia, will be leveraged with other research. It will also include a demonstration of a new security screener proficiency evaluation and reporting technology.

The FHWA is evaluating driver behavior and performance at complex intersections, such as traffic circles, as well as highway design factors that may influence driver maneuver errors. The results of this activity will be used to help design driver error taxonomies and developing an interactive highway safety design model.

In ITS, the FHWA is assessing user interface issues in ground traffic management systems, such as the Advanced Traffic Management System. They are also developing human factors guidelines for the Intelligent Vehicle Initiatives program.

FHWA is placing special emphasis on the United States trend toward increasing numbers of older drivers and the implications of this trend on highway safety. Human factors research products include highway systems design guidelines and handbooks based upon empirical human performance data collected in the laboratory and in controlled, on-the-road tests.

Long Term

Existing NHTSA and FHWA research efforts will be extended to analyze driver/vehicle performance systems using fixed-base and moving-base driving simulators. These could be made available at roadside stops to advise drivers of the onset of fatigue and other temporary deteriorations in driving abilities. The system costs can be significantly reduced through the use of recent advances in micro-electro-mechanical devices. This same approach will be applied to NHTSA research to develop in-vehicle performance aids and individualized advisory alerts for aging drivers.

A DOT Human Factors Coordinating Committee is underway to address issues that are common to every mode of transportation. The Initiative will involve advanced instructional technology, alertness enhancement, and new methods for fatigue detection. In the future, the Committee will establish cooperative human factors research directions for all DOT agencies that may lead to change in near-term programs. The Department will also participate in multi-agency research to incorporate work-related and environmental factors and the restorative effects of countermeasures within existing human factor alertness models.

The FHWA human factors has three long term human factor programs. These are:

- Developing human factors guidelines for the Intelligent Vehicle Initiative program;
- Issuing a comprehensive human factors highway safety handbook, including driver performance and older driver issues; and
- Defining the needs of younger drivers in terms of driving performance, operational features, and geometric design.

B. Advanced Materials and Structures

Technical advances in the defense and the consumer sectors have produced a wide variety of new materials and structures techniques. This rich inventory includes high-performance concrete, new steel alloys, innovative composite materials and adhesives, imaginative structural concepts, computer-aided design techniques, automated construction and maintenance tools, and new approaches to corrosion protection and control. Enabling research in this area supports the application of these advances to the transportation infrastructure. There are at least four major government/industry programs in which this is now occurring. The first of these is the DOD Technology Reinvestment Program, where research has been conducted on the low cost processing of specialty metals and applications of ceramic materials.

The second program, under the National Institute of Science and Technology, has a large research budget and a number of projects. This program covers enabling surfacing, welding, forming, casting, and joining processing technologies, all of which can be used in the future improved manufacture of aircraft, ships, buses and other ground vehicles.

A third effort, managed for DOT by the Transportation Research Board of the National Research Council, is the IDEA (Innovations Deserving Exploratory Analysis) program that covers many advanced materials for vehicles and pavement construction and maintenance. Materials concepts for the 21st century include layered systems for surface hardening, total energy absorption and collision protection, instant fix composites for structural repair, and the application of robotics to the construction process.

Lastly, the relatively new discipline of micro/nanotechnology has made possible such transportation-related advances as miniature gyroscopes and other electromechanical devices, and atomic-level coating of metallic surfaces to achieve super-hardening, low friction, and enhanced corrosion protection.

The near term Advanced Materials and Structures research programs are grouped into four categories. These are: *(1) Metals; (2) Composites and Adhesives; (3) Pavements;* and *(4) Structures and Containers.*

Near Term

1. Metals

The MARAD, working with the Interagency Ship Structure Committee, is conducting research on advanced steels and aluminum alloys in its Shipbuilding Standards Program.

The FHWA is testing ultra-high strength steel in the laboratory.

The FRA is investigating new alloying and heat treating methods to improve the safety and increase the service life of rails, rail track switches, and train wheels. They are evaluating the fitness for service and failure prevention characteristics of rail wheels and other materials as a function of such factors as manufacturing processes and stress loads. They are conducting research on the impacts on safety from the use of new lubrication and rail grinding methods. They are also developing an alternative locomotive-mounted device for detecting broken rails ahead of trains.

The FTA is also studying the development of low cost, low maintenance rails for heavy, medium, and light transit railroads.

2. Composites and Adhesives

The FHWA is researching the engineering properties of composites, such as fiber reinforced plastics, and assessing the feasibility of such concepts as composite guardrails and timber-reinforced composites.

The FAA's Advanced Materials/ Structural Safety program is investigating the mechanical properties of composite and other advanced materials used for aircraft body and interior components.

The FAA, in its aircraft fire research and safety programs, is scaling up benzoxane chemistry to produce fire resistant, non-toxic interior panels to evaluate their heat release rate. They will develop plastic and composite materials that produce a 50% reduction in heat release.

The Coast Guard is investigating the fire safety of composite airframes.

MARAD, working with the Interagency Ship Structure Committee, is studying the use of composites in its Shipbuilding Standards Program.

3. *Pavements*

The Long Term Pavement Performance (LTPP) program, initiated under the FHWA Strategic Highway Research Program (SHRP) in 1987, is a 20-year study of the characteristics of different asphalt and pavement concepts involving 2,800 separate in-service test pavement segments across the United States and Canada. This program will also research asphalt properties at molecular and chemical structure levels.

The FAA has a research program to develop an integrated method for airport pavement design that employs layered elastic theory. The agency also manages an Airport Pavement Technology program, and has designated the University of Illinois at Urbana-Champaign as its "Center of Excellence" for airport pavement research.

4. *Structures and Containers.*

One of NHTSA's responsibilities in the PNGV program is to determine the structural integrity of aluminum and composite-intensive materials for these future vehicles.

As a part of NHTSA's crashworthiness program, they are doing research on air bags to improve their effectiveness and to provide occupant protection under various crash conditions. They are also researching improvements in vehicle structure, occupant compartment design, and restraint systems to reduce crash-related deaths and injuries.

The FHWA is evaluating the durability and maintenance characteristics of high performance concrete bridges in a number of states.

The FAA's Aircraft and Container Hardening program seeks to reduce the damage effects caused by small explosive detonations in commercial aircraft and air freight containers by using advanced materials in their construction. They are also studying the protection of narrow bodied aircraft from explosive destruction by a limited number of cargo and passenger bags.

The FAA is researching the improvement of fire safety systems to prevent uncontrollable in-flight fires, increase post-crash fire survival rates, and develop ultra-fire resistant cabin materials.

Long Term

A number of ongoing FHWA research projects directly relate to this enabling research topic, and continue to promise important results in the future. These include such projects as: performing distress analysis on high performance concrete; evaluating high performance steel; characterizing the performance, structural shapes and repair requirements of installed composite materials; and continuing the data gathering and analysis associated with their Long Term pavement Performance (LTPP) program.

DOT will begin a new program to coordinate multi-modal research on damage tolerant structures and high-performance materials for surface, air and marine applications. The FAA's Aircraft and Container Hardening program may lead to low cost, lightweight, hardened container materials that could eliminate or mitigate the threat of explosives aboard commercial aircraft.

Finally, the FRA is looking at new technologies and materials to improve the safety of rails, switches, wheels, freight cars, and passenger cars.

C. Computer, Information, and Communications Systems

Modern transportation systems require accurate, timely information. As information infrastructures are overlaid onto the physical transportation infrastructure, ready access to information is becoming integrated into virtually all system elements and functions. However, computer and communications systems often cannot exchange data quickly or accurately because different segments of the transportation system handle information in different ways. Thus, the federal government has a critical role to play in helping to develop uniform standards for transportation-related computer, information, and communication systems.

There is a wide range of near-term transportation research that involves the coupling of computers, communications and location information on cars, airplanes, trains, and ships. Most of this research falls within two major DOT initiatives: the modernization of the National Airspace System and its evolution to "free flight" by the FAA, and the ITS program. Both of these initiatives obtain location information from the DOD Global

Positioning System (GPS) satellite constellation or other specialized navigation and surveillance systems, combine it with data from many other sources, and communicate the processed information directly to both dispersed transportation users and system operators at central control and monitoring facilities.

A version of GPS, known as Differential GPS (DGPS), uses a local receiver that has been location surveyed to provide corrections to the satellite signals in order to provide true positions with greater accuracies within the range of 0.5 to 5 meters. DGPS will provide these accuracies in a wide number of current and future land, air and marine applications that include multiply-sampled signals for geodetic surveys with accuracies as good as 10 centimeters.

In addition, as transportation's dependency on increasingly complex intelligent systems mounts, it also becomes more vulnerable to accidental or deliberate service interruptions. Thus, other federal and DOT research is conducted on systems development, modeling, and verification techniques to provide the users of these systems with high levels of security, reliability, and restorability.

Although *computer, information, and communications* systems often go together, an effort has been made here to group the near term enabling research programs into either: (1) *Computer Systems; (2) Information Systems;* or (*3) Communications* that are based on their primary purpose.

Near Term

1. *Computer Systems*

The FTA is studying the control and monitoring needed for a mixed rail corridor operation of freight and transit trains.

The FRA's Positive Train Control (PTC) projects involve the use of ITS technologies. These include digital data links to connect locomotives, maintenance-of way equipment, wayside base radios, and control centers. On-board and control center computers, positioning systems, data radios, and display screens on locomotives and maintenance-of-way equipment will be employed. The positioning systems (e.g., differential GPS) on the vehicles will inform the control centers of their location via the data link. The on-board computers will compare the actual location with the movement authority and, if there is a possible violation, the computers will stop the trains.

The FHWA is developing software and testing methods to insure that large operating systems are robust and reliable.

The FTA is studying the security from electronic intrusions of their information systems, beginning with electronic fare payment systems and telecommunications. They are also addressing innovative passenger surveillance and security systems, and computer system security against electronic intrusions.

The FAA is integrating airborne flight management computer operations with ground-based air traffic management automation.

2. *Information Systems*

New surveillance and identification technologies are being incorporated by the FAA into airport surface movement advisor concepts to integrate the location of arriving and departing aircraft with taxiing and airborne aircraft.

The FAA is developing a new ground-side Automatic Dependent Surveillance-Broadcast (ADS-B) system that will derive aircraft position from an airborne global navigation satellite system and use a two-way data link to provide aircraft separation services.

The FAA's current ground-based navigation and landing support systems are being replaced with low earth orbit satellites and ground stations to achieve high accuracy aircraft differential GPS position and altitude information. The information will be used for air traffic control in en route and terminal airspaces and for precision approaches. In a related area, the FAA will improve the efficiency of the NAS by implementing a low cost surveillance system that enables "free flight" capabilities, minimizes runway incursions, and provides coverage in existing non-radar areas.

The FAA is also improving aviation weather analysis and forecasting capabilities by developing algorithms for the next generation weather radar and other new radars, as well as developing an airborne humidity sensor.

The FAA is researching the development of standards and guidelines for the certification and end-to-end testing of air/ground software intensive systems. They are also studying applying commercial-off-the shelf items within the NAS ground systems and avionics.

A joint FAA/ NASA program seeks to apply advanced technologies to improve aviation safety, reduce delays, remove constraints to flight operations, provide better management of airspace and airports, and develop new aircraft avionics, such as airborne weather graphics of hazard alerts (wind shear, microbursts, and gust fronts).

In its Transit Intelligent Transportation Systems program (previously known as the Advanced Public Transportation Systems, or APTS) the FTA is researching advanced transit customer information (e.g., routes, locations, and arrival times) technology through its "smart" kiosk systems at transit stations. They are also evaluating advanced bus stop signs, regional fleet management, route guidance, multi-purpose "smart" cards for passengers, and other technology advances for possible application to transit.

The FTA is researching mobility management, welfare to work, rider service and reliability, and low density area planning, including rural areas and services for the disabled and citizens impacted by welfare reform. The FTA is also working with the FAA to improve the transit accessibility at airports by providing travelers with information on route options and service status.

The FTA is evaluating possible increases in ridership that would result if their fixed route public transit services were changed to more flexible routes. They are doing research to develop better estimates of transit conditions, performance, benefits, and the relationships between transit and land use planning. They are also doing research to improve transit services for the elderly, the disadvantaged, potential welfare to work ridership, and in low density areas.

The FRA is evaluating different advanced Vehicle Proximity Alert Systems that can provide a visual and audible warning to alert motor vehicle drivers that a train is approaching a highway-rail grade crossing.

The U.S. Coast Guard is developing intelligent interfaces for ships, including shipboard navigation equipment, for automatically distributing safety and vessel traffic information to waterways users.

The Coast Guard's Waterways Safety and Management program focuses on emerging and new navigation, communication, display and information technologies for application to such Coast Guard systems as buoys and short range aids to navigation. The agency is studying improved search and rescue capabilities to speed up the responses to emergencies and to develop better tools for locating persons and vessels in distress. The are also researching improved intelligence, surveillance and vessel search capabilities to improve their law enforcement mission.

FHWA is using GPS and data logger-equipped vehicles for travel time studies and for supplementing personal travel diaries.

MARAD is developing a Global Deployment Analysis System for assessing total sealift requirements.

The Office of Hazardous Materials Safety in RSPA has a program to integrate hazardous material registration data, assessing the feasibility of enabling industry to file incident reports electronically, and evaluating hazardous materials risks and future technologies. RSPA is also developing an improved national response management information system for emergency transportation.

FTA is researching the causes of transit incidents, as well as crash avoidance and collision warning systems.

The Department's Bureau of Transportation Statistics (BTS) is assessing the potential impacts of various types of future PNGV vehicles on the transportation system as a whole. This research is being conducted by RSPA's Volpe National Transportation Systems Center and covers such areas as: changes in fuel and materials supply systems and infrastructures; and the safety of the new vehicle designs, components and highway barriers.

Within the ITS program, FHWA, FTA and NHTSA are collaborating on the Intelligent Vehicle Initiative program to pursue a wide range of ITS technologies to improve the safety, efficiency, and mobility of transportation systems. The program will develop: critical subsystems of the most promising concepts; on-board diagnostics to warn drivers of faulty systems (e.g., brakes and lights); vehicle emissions monitoring systems; enhancements to crash avoidance through vehicle-to-vehicle and limited vehicle-to-roadside communication and cooperation; commercial motor vehicle monitoring systems; techniques for the automated identification of vehicles crossing borders; and an assessment of user demand and societal and institutional issues.

The ITS information systems technologies include forward-looking radars, blind spot sensors, and color video sensing. Included in the IVI program are evaluations of: ITS rural applications such as weather and safety advisories and mobility management; prototype public transit demonstration systems such as passenger smart cards, transit information, and fleet management; and prototype collision avoidance systems. This latter evaluation will cover safety aspects of automatic collision notification, intelligent cruise control, and automatic on-the-road inspecting of heavy trucks.

NHTSA is researching advanced occupant protection in various crash modes, including frontal, side, and rollover crashes. Priorities in this area include roof crush resistance, advanced restraints, rollover protection, vehicle-to-vehicle collision compatibility, aggressivity of interior surfaces, and offset frontal crashes. The FAA is working with NHTSA to explore improvements in aircraft child restraints.

NHTSA is addressing the prevention of crash fires and their mitigation through research on vehicle fuel system crashworthiness, flammability of vehicle interior materials, crash and burn tests, and the evaluation of vehicle fluids and electrical systems. They also have an Automated Collision Notification program in the ITS program to reduce the time between a crash and the delivery of hospital-based emergency services to victims, especially for unwitnessed, single person crashes in rural areas. In addition, NHTSA is evaluating the potential benefits of ITS-based collision avoidance systems, and is assessing the safety impacts of new ITS products.

The development of ITS architecture and standards will ensure the interoperability and compatibility of ITS applications, systems and components, as well as the standardization of the efficient processing of time-varying transit information on a Geographical Information System (GIS). Also under development as a part of the ITS program are the following:

- Real-time traffic adaptive control systems;
- Functional requirements and operational needs for wide-area traffic control;
- Technical options for the increased visibility of differential GPS signals on the ground and in areas where the satellite signal reception is inadequate (e.g., valleys, forests, high buildings); and
- Research on obtaining and distributing weather information to highway maintenance/operations units and road users.

The FAA's modernization of the National Airspace System and the transition to "free flight" is generating a number of important research efforts in the area of improved computer, information and communications applications. These projects are directed at developing such improvements as advanced traffic management techniques to reduce aircraft ground delays, new air traffic control decision support systems, and enhanced data exchange and collaborative decision-making. For example, GPS data capabilities and new data links will be applied to help automate oceanic flight separation planning and traffic flow management.

A number of information system research programs are underway within FAA. These include projects designed to:

- Enhance current generation airport baggage and passenger screening system performance, including the development of methods to detect nonmetallic weapons and liquid explosives;
- Evaluate new security technology and procedures integrated within the airport environment;
- Provide aviation field inspectors, certification engineers, and industry specialists with safety management automation tools for aircraft type certification, flight operations, and airworthiness assessments;
- Enact procedures to utilize multiple-runway capacity more effectively during instrument meteorological conditions with the aid of advanced surveillance technologies, including a precision runway monitor with electronically scanned antennas;
- Facilitate reliable, all-weather operations for general aviation and vertical flight passenger and cargo aircraft;
- Establish standards for reduced vertical and horizontal separations in oceanic airspace;
- Produce separation, approach and route procedures for "free flight" and analyze methods to assess their impacts on pilots and air traffic controllers;
- Increase the understanding of catastrophic aircraft structural, turbine engine and flight control failures, and implement improved certification procedures and regulations to mitigate these events; and
- Incorporate the exchange of airline schedule and flight-critical information between air traffic control, the airlines, and airport operators in a Cooperative Decision-Making process.

The FAA has two major research and development programs to incorporate GPS capabilities within their future National Airspace System. The first of these is the Wide Area Augmentation System for en route airspace, which will also employ two way air-ground data links for the automatic dependent surveillance of air traffic. The second is the Local Area Augmentation System for terminal air traffic, which will use differential GPS with a two-way data link for precision airport approaches.

3. Communications Systems

The FAA is developing new special purpose air-to-ground and ground-to-air data link capabilities that will include airborne graphical weather services. The FAA is also studying low cost general aviation avionics employing new satellite and data link technologies that will allow general aviation aircraft to become repeater stations transmitting continuous weather observations.

The Coast Guard is assessing new and emerging commercial communications systems to meet mobile communications requirements and improve their reliability and effectiveness; as well as innovative systems and methods to provide operators with single-point access to all current and historical reporting requirements.

In its Communication-Based Train Control program, the FTA is beginning the automation of transit trains to achieve improved "smart" grade crossing protection, coordination with intelligent road systems, and faster service with less vehicles.

As a part of the ITS program, the FHWA is developing a new data communications protocol that will allow communication between traffic control devices of different types and manufacturers. Other ITS research is being conducted to:

- Resolve the technical issues related to the allocation of the 5850-5925 Megahertz band intended for multiple ITS uses;
- Provide a standardized high speed FM carrier system as a data channel for vehicles;
- Establish an AM sub-carrier system for rural and wide-area ITS vehicle communications; and
- Identify potential interference issues and alternative systems for ITS communications.

<u>Long Term</u>

The FAA has already begun to study 21st century communications technology, such as personal communications systems and low earth and medium earth orbiting satellites, and to assess the extent to which they may satisfy future National Airspace System requirements for reliable and high capacity communications. The study will also ensure conformance with the open systems interface model to enable the use of off-the-shelf commercial products. In similar efforts, FHWA is investigating driver assistance automation with and without communications with highway infrastructure components, as well as new methods and procedures to quantify the impact of incorporating advanced technologies within the transportation system.

DOT is also actively engaged in Enabling Research covering a number of joint and cooperative ventures with other federal agencies, the private sector and the academic community. For example, under a cooperative program with DARPA and industry, both the FAA and the FHWA can seek to develop and incorporate wearable, compact, ultra-wide band, spectrum efficient, clear channel radios for land, air, and marine transportation uses.

The U.S. Coast Guard is initiating a Small Business Innovative Research (SBIR) solicitation to design the interoperable radio systems that will communicate over the numerous different frequency bands and modulations used by the Coast Guard, other government agencies, and public safety organizations.

DOT can research the development of a next-generation Internet that will provide a comprehensive taxonomy, with graphics in an improved search engine, to improve access to transportation information. DOT can also coordinate research among its modal agencies to improve software and information assurance and expand the applications of GPS and GIS in transportation systems.

The Department can collaborate on the development of photonics (the use of photons in the infrared through ultraviolet spectrum) for such applications as automobile dashboard instrumentation, optical roadside sensors, and fiber optic links that do not require an electronic connection. Other joint projects include: non-intrusive ("artifact free") real-time or quasi real-time measurements of computer performance and security monitoring of electronic intrusions; and the development of wide-view, high resolution, three dimensional displays of vehicles in traffic.

D. Energy, Propulsion, and Environment Engineering

The transportation challenges presented by the emergence of the global economy and the expansion of long-distance passenger travel and cargo shipments have significant environmental and energy consequences. However, market forces generally provide little incentive for the private sector to undertake research in this key area on its own. Therefore, exploring longer term, higher risk technologies and strategies to address environmental issues necessitates a substantial federal research and development role.

Achieving sustainable development that meets today's needs without jeopardizing future generations requires research advances to minimize transportation's energy and environmental impacts. This research addresses issues such as: air pollution from highway vehicles; the environmental aspects of highway operations, such as noise and runoff; and efforts to reduce aircraft emissions. It also includes electric propulsion and battery concepts, advanced internal combustion engines, hybrid designs, new aircraft engine concepts, and the application of innovations such as fuel cells and flywheel energy storage.

The near term research programs in this enabling technology area are organized in four categories. These are: (1) *Engines and Fuels; (2) Emissions; (3) Advanced Batteries and Vehicle Electronic Systems;* and *(4) Light Weight Vehicles.*

Near Term

1. *Engines and Fuels*

In research similar to that in the PNGV for automobiles, the FTA is researching electric and hybrid-electric buses in its Advanced Technology Transit Bus (ATTB) program.

The Coast Guard is researching fuel conservation alternatives, including alternative fuels and electronic engine control systems. It is also assessing the possible replacement of existing diesel-electric propulsion systems with advanced fuel cell modules by participating with MARAD, RSPA, DARPA, the U.S. Navy, NOAA, and DOE, in a joint project to build and test a nominal 500 kilowatt fuel cell demonstration module.

Under the FTA's Advanced Bus Propulsion Systems program, development of hybrid-electric and electric technologies and vehicles are taking place. FTA's fuel cell transit bus program is developing and demonstrating both the phosphoric acid fuel cell and the proton exchange membrane fuel cell as the propulsion system for 40-foot transit buses. The FTA is continuing its involvement in the safety issues of alternative fuels in transit applications.

The FRA is developing a light-weight, turbine-powered locomotive suitable for high-speed intercity passenger train operations. They are also continuing research and development of an energy storage flywheel device and a high-speed alternator for incorporation into the locomotive.

The FAA is developing improved manufacturing process standards for premium quality titanium alloy turbine rotor components. They are also studying the prediction of hard crack formation and growth and reliability improvements in titanium engine components.

2. *Emissions*

The Coast Guard is studying exhaust emission levels of sulfur dioxide and nitrous oxide on its vessels to develop strategies to reduce pollution.

The FAA is evaluating replacement gases for halon in fire suppression systems and replacement additives for lead in aviation gasoline. They are also doing research on industry-provided lead-free formulation candidates to replace the low lead aviation gasoline now in use.

The FAA is continuing three cooperative noise reduction program with NASA. The program will identify technologies for U.S. manufacturers to develop quieter helicopters and subsonic jet transport and light propeller-drive airplanes. The FAA is also studying lightning and high intensity radiated fields upset phenomenon.

The FRA is addressing the mitigation of railroad noise through active suppression, and research into noise that can come either from the train itself or specific components, that might be an impediment to the deployment of high speed systems.

3. Advanced Batteries and Vehicle Electronic Systems

The FTA is demonstrating and evaluating a number of advanced batteries and recharging options for transit bus applications. They are also demonstrating and evaluating a number of hybrid-electric and electric components and subsystems for transit bus applications.

4. Light Weight Vehicles

The FTA is researching light weight rail transit vehicles to reduce their manufacturing costs and wheel and rail wear. They are also studying the development of a small (30 foot long), heavy duty bus that will have a 42% longer life than today's shorter buses (equaling the life of 40 foot buses).

Long Term

Several DOT research topics in this category have significant potential long-term impacts. For example, the FAA has a cooperative program with the aircraft industry to improve the reliability of current and future high energy rotating components in propulsion systems. This program will also assess fuel temperatures of high-speed civil transports and thermal and mechanical fatigue and fracture problems that may exist with the use of super alloys, ceramics, and coatings in future engines. The MARAD interagency marine fuel cell development research into advanced electric propulsion technology may also lead to major improvements in the efficiency and environmentally friendly characteristics of ship propulsion systems.

E. Sensing and Measurement

DOT's sensing and measurement enabling research addresses a number of transportation-related applications. These include such topics as: monitoring ground traffic; identifying ground vehicle and aircraft hazards; assessing the quality of pavements, bridges and other structures; determining methods for improving air navigation and vessel and aircraft safety and security; advanced weather, air pollution, and explosives sensors; and new night vision techniques. Many of these programs can also benefit from the recent introduction of new low cost microminiature devices that have been developed by industry. These include "smart" sensing devices (like shape memory alloys) that can adapt to structural stresses, small in-vehicle emission sensors, and miniature gyroscopes and accelerometers that will form inertial platforms to measure vehicle rotational stability, speed, and acceleration forces.

The near term programs in the sensing and measurement technology are grouped into four categories. The first involves *sensing* of the *environment* (e.g., winds, ocean currents). This is followed by *monitoring of vehicles and drivers; non-destructive testing* measurements of materials; and *position sensing.*

Near Term

1. *Environment Sensing*

The FHWA is developing a new ultraviolet head lighting in combination with fluorescent delineation and signing to improve night-time driving visibility.

The FAA is developing a system to improve the detection, monitoring and alerting of aircraft to hazardous mountain winds. They also have a SOCRATES (Sensor for Optically Characterizing Ring-eddy Atmosphere Turbulence Emanating Sound) ground system project that will provide an early warning to aviation of clear air turbulence, wind shear, and wake vortices from the very low frequency signals (50 Hz) signals of these hazards.

The FAA is developing an aviation gridded weather forecasting system that will provide improved information on icing conditions, storm growth and decay, turbulence and airborne humidity. They are studying the remote sensing of icing and ice droplet accretions on aircraft, along with prototype technology to assess icing conditions remotely. They are also developing automated airline passenger ticket screening, and bulk and trace detection systems.

The FAA is studying disease transmissions via aerosols in an aircraft cabin environment. They are developing an aircraft tower environment that can provide an operationally useful enhanced or synthetic view of the airport surface during periods of low or zero visibility.

To improve transit security in subways, the FTA is researching the integration of a number of Urban Chemical Release Detector (UCRD) sensors to reduce the false alarm rates caused by existing subway interferents (e.g., normal gases and vapors).

The Coast Guard is developing analytical methods for determining ocean surface currents for search and rescue mission planning. They are also assessing the search performance of night vision goggles and their use with a laser illuminator system on search and rescue helicopters.

The FTA is researching thermal scanning, electromagnetic pulsing, radar, and high resolution ultrasonics for the inspection of transit tunnel degradations (e.g., vibration, water).

The FRA is studying the mitigation of railroad noise through active suppression, and researching noise that comes from the train itself or specific components that might be an impediment to the deployment of high speed trains.

2. Monitoring of Vehicles and Drivers

The FHWA is investigating the use of a 'black box' device, developed at Sandia National Laboratories, on commercial motor vehicles to assist in understanding the causes of crashes. A related capability to use GPS position sensing with automobile condition in an accident (e.g., front and side damage, and overturned vehicle) for automated 911 emergency responses has already been developed commercially.

NHTSA is developing improved methods for the detection of impaired drivers' alcohol and drug use, to alter their unsafe behavior and attitudes.

3. Non-destructive Testing

The FHWA is conducting extensive research in its Non-Destructive Evaluation (NDE) program. It is evaluating over twenty different wave emitting devices for measuring the quality of bridge beams, decks, and foundations, and is constructing a non-destructive evaluations calibration facility.

The FAA is developing ultrasonic and eddy current inspection tools for the in-service inspection of aircraft engine components.

4. Position Sensing

The FHWA is investigating new surveillance capabilities for monitoring and responding to wide-area traffic conditions.

The FAA is studying the concept of transitioning to a satellite-based navigation system that includes a strategy for decommissioning older ground-based systems. The FAA is also researching the augmentation of GPS to meet civil aviation needs with a single navigation receiver.

The FAA is completing the development of prototype airport surface technologies to allow operations in reduced visibility. Low cost S-band, phased-array, and frequency modulated continuous wave radars, and other secondary sensors will be evaluated with the aid of an aircraft target detector.

Long Term

FHWA's research on "smart pavements" and weather reporting could lead to the introduction of low cost miniature sensors and short range radio frequency transmitters that could automatically report highway weather and road conditions to a central traffic management center.

FHWA and NHTSA can collaborate with industry to develop low cost miniature inertial platforms to measure and enable the automatic correction of unstable vehicle conditions. The FAA can investigate using the Sandia "black box" concept aboard general aviation aircraft, as well as high-speed airline passenger screening systems that combine voice, physiological, and travel profile recognition techniques.

The FAA is initiating an SBIR solicitation to assess the feasibility of a cosmic radiation monitor of single event upsets by high energy particles that could adversely affect new advanced digital avionics and flight control systems. They will also study the use of an airborne version of the SOCRATES system so that pilots can get more immediate warnings of clear air turbulence, wind shear, and wake vortices.

The FHWA is initiating two SBIR solicitations that may also result in long-term R&D products. The first of these is a feasibility study of techniques to develop an automatic truck or trailer body and cargo classifier using advanced video or other non-intrusive detectors. The second is a study that may ultimately develop a low cost, high resolution infrared laser sensor of pavement profiles that can be taken at highway speeds.

NHTSA is initiating an SBIR solicitation for a low cost, low maintenance system that may significantly improve the recognition of bicycles by motorists from much longer distances.

The U.S. Coast Guard is initiating an SBIR solicitation that may, over the long term, provide an inexpensive collision warning device for the detection of large vessel locations and speeds that can be used by recreational boaters.

Finally, the Department can collaborate with the EPA and other federal agencies on a new and more effective family of pollution sensors. These will include advanced, wide area, remote laser sensors that can pinpoint air pollution sources over a large region. DOT can also promote research on micro/nanotechnologies and portable, broad-band, real time monitoring and detection systems.

F. Analysis, Modeling, Design and Construction Tools

Research in this area focuses on developing and improving the tools, knowledge bases, and techniques used by researchers to investigate specific technical or operational topics in transportation. There are many different types of DOT analysis, modeling, and construction tools. They can be classified in four different categories: (1) *characterizing the environment* of the vehicle, aircraft, or vessel operators; (2) *improving safety*; (3) *improving operating procedures*, particularly where major changes occur in transportation systems due to the introduction of new technologies or concepts such as ITS or "free flight; and (4) *risk, investment, and planning analyses.*

Near Term

1. *Characterizing the Environment*

FHWA and NHTSA are both active in characterizing the motor vehicle operating environment. The National Advanced Driving Simulator being constructed at Iowa State University will be used for human factor, safety, and vehicle design research. FHWA is applying emerging behavior theory to model driver behavior in a traffic simulation environment.

The FRA's Research and Locomotive Evaluator/Simulator (RALES), located at the Illinois Institute of Technology Research Institute, is used in locomotive engineer workload, stress, and fatigue, and fatigue mitigation studies, and for training purposes. It is a full-motion based simulator, with a visual projection display and a sound system augmenting the motion, that provides a high-fidelity simulation of the in-cab experience of a locomotive engineer.

The FAA is developing an improved global aviation emissions forecasting model for the evaluation of the atmospheric effects of aviation. They are also studying the improved characterization of ionospheric conditions that might affect the availability of GPS signals.

2. *Improving Safety*

NHTSA is performing biomechanics research to address the human consequences of automobile crashes. Impact injury research, human surrogates, and computer models are used at its National Transportation Biomedical Research Center (NTBRC) to evaluate the extent and severity of potential crash injuries.

NHTSA is studying the feasibility of discrete event simulation modeling of the early phase of air bag deployment. They are also developing a vehicle occupant simulation model to evaluate head and chest injury severity during crashes, particularly for brain soft tissue damage from head rotational motion.

NHTSA is studying the physical conditions and human consequences of real-world crashes in three areas. These are: (1) gaining an understanding of human body experiences in a crash and their relationship to the extent and severity of resulting injuries; (2) constructing dummy components and other mechanical trauma assessment devices that evaluate human risk; and (3) developing advanced computer models to understand human injury mechanisms. Emphasis in these areas will be on the biomechanics of pediatric injuries and the development of test dummies for three and six year-old children and females.

For the PNGV program, NHTSA is developing finite element models for evaluating both the crashworthiness of new vehicle structural and material concepts, as well as aggressivity and compatibility factors for future cars of different sizes during crashes.

Using computer simulation, FHWA has demonstrated major successes in evaluating the performance of roadside hardware designs (such as slip-base sign and luminaire supports, guardrails, median concrete barriers, end terminals, etc.). Major increases in computational efficiency have been demonstrated using parallel processing technology. For example, a crash simulation that would take a week of processing time on a standalone work station takes less than one-half day on eight similar processors running in parallel. In the near future, this will allow efficient modeling of crashes and results in computer tools and models that can be run quickly to obtain desired crash performance analyses.

The FAA is developing models and inspection procedures to insure the safety of aging aircraft against materials fatigue and fractures due to corrosion. They are modeling the uncontained debris from engine rotating components and a model for the airframe manufacturers' evaluation of aircraft catastrophic failure protection. They are also developing finite element models for the evaluation of airport pre-stressed fibrous concrete pavements and joints, as well as an analytic model for composite structures to impact damage.

The FAA, NASA, and RSPA's Volpe National Transportation Systems Center are collaborating on a joint program to develop models and simulations that characterize aircraft wake vortex hazards. Flight test simulators will also be developed to determine if reducing the current aircraft separation standards is feasible.

The FRA is developing models to evaluate the crashworthiness of locomotives and railroad passenger cars to reduce the probability of fatalities and injuries from end-to-end and raking impacts. They are modeling not only the existing structures of cars and locomotives, but also crush zones and seating, passenger restraints, and compartmentalization techniques.

The FHWA is developing a computer based tool that will be used to evaluate the safety implications of geometric design alternatives throughout the planning, design and review phases of highway construction and reconstruction projects. The Interactive Highway Safety Design Module (IHSDM) is being developed under the council of seven State departments of transportation to assure that the final product is responsive to the needs of the user community. FHWA has established cooperative research and development agreements with civil design software vendors so that IHSDM will be integrated into commercial design products delivered to highway planners and designers.

3. Improving Operating Procedures

The FAA is developing simulations of the air traffic control center airway environment to help increase capacity, reduce delays, and lower maintenance and operating costs. It is also improving two existing models (SIMMOD and NASPAC) of airport layout design and airspace routings, and developing the National Airspace System Infrastructure Simulation (NASSIM) to evaluate current and new hardware programs against "free flight" requirements.

NASA is modeling the operation of en route air traffic control sectors and the integration of this capability into a network model of the National Airspace System to estimate the fuel savings from optimal routes obtained from the implementation of "free flight".

The FAA will complete the development of a passenger and baggage flow modeling tool to enable less intrusive and higher throughput security screening at airports. They will begin the modeling and simulation of proposed Decision Support System data link services. The FAA is also evaluating the suitability of analytical modeling as a substitute for evacuation tests during the certification of new passenger aircraft.

The FAA is performing both operational analysis and human-in-the-loop simulations of new NAS air traffic control operational concepts. These include analysis of sector sizing, how to identify traffic flow and density in a non-route environment, how to size and shape the sectors to meet the flow, and how sectorization is to be used in the future.

The FTA is developing a simulation to assess improvements to transit quality of service, customer satisfaction, paratransit capacity, different fare collection systems, and bus clearance and boarding and alighting times. They are developing a simulation of the transit environment, including medical triage, contingency transit, emergency evacuation routes, and vulnerable location points, all of which will aid security personnel in responding to catastrophic transportation events. Finally, FTA is researching advanced simulators for the training of transit vehicle drivers to adapt to real-time location, route, and vehicle status information (e.g., fuel economy, emissions).

The Coast Guard is developing software models to improve search planning tools and methods, to evaluate waterway performance, to determine ship transit risks, and to improve responses to oil spills.

MARAD is developing a prototype intermodal freight planning model.

4. *Risk, Investment, and Planning Analysis*

The FAA is investigating models of the future National Airspace System to guide R&D investment decisions.

The Coast Guard is developing software models of how ships use coastal zone waterways, to aid in capacity planning.

FHWA is developing analytical models for estimating ITS-related fuel savings and emission reductions, as well as other safety, capacity, economic and public benefits.

FHWA is creating an Interactive Highway Safety Design Model (IHSDM) to evaluate the safety implications of highway planning and design decisions. It is also working on models of risk and uncertainty in transportation, data collection and panel survey mechanisms (for the 2000 Census), and multimodal issues, including tradeoffs to optimize expenditures among the modes, and congestion relief and mobility enhancement strategies.

The FRA is undertaking corridor risk analyses, as well as cost and business benefit analyses, of Positive Train Control systems to support their collaborative rulemaking activity.

In its Aviation Safety Risk Analysis program, the FAA is developing and enhancing critical performance measures on aircraft design and maintenance, discrepancy reports, air carriers, air agencies, and air personnel.

<u>Long Term</u>

Among the projects with a longer term horizon, MARAD's National Coastal Shipping Study is researching the modeling and design of innovative waterborne transportation systems. The FAA is developing models that can be used to predict the noise profiles of rotorcraft.

There are a number of initiatives in the FHWA, including: an Interactive Highway Safety Design model for two-lane rural and multi-lane roads; models employing pattern recognition and neuronets to perform hydraulic analysis and to assess pavement performance and the fatigue life of structures; and advanced computer software and systems to provide more accurate assessments and analysis of transportation systems and technologies.

DOT is developing models to determine the impacts of telecommuting on transportation congestion, delay, and pollution. For example, the Office of the Assistant Secretary for Policy has been working with the FHWA, FTA, EPA and DOE in sponsoring the creation of a large, Transportation Analysis and Simulation (TRANSIM) system by Los Alamos National Laboratories. TRANSIM will be a valuable micro-simulation forecasting model that will estimate activity-based travel demand (e.g., to work, shopping, and recreation), intermodal trip planning, and traffic congestion and emission concentrations.

DOT is working with the Department of Commerce on models that will predict the effects of population shifts on transportation infrastructures, and with other federal agencies on models that will determine the investments needed to prevent unauthorized electronic intrusions into key transportation information systems. DOT will also develop advanced multi-modal models for the simultaneous design of vehicles with their infrastructures, and simulation tools for optimal system design, testing and operations.

CHAPTER V: Measuring Success

A. The Government Performance and Results Act (GPRA)

The Government Performance and Results Act (GPRA), P.L. 103-62, enacted on August 3, 1993, requires the development and use of performance measures for agency management. Ultimately, over a seven-year period, it was to lead to use of performance measures for allocating budgets.

GPRA focuses on assessment of the broad outcomes of government programs, rather than particular outputs produced by agency expenditures. The difference between "outcomes," "outputs" and "impacts" is central to GPRA. These distinctions are conceptually straightforward:

Outputs -- *The direct, tangible result of an activity.* Products or services generated by a program or organization and provided to the public or to other programs or organizations. Generally, outputs can be measured on an annual basis.

Outcomes -- *A result, effect, or consequence of the output in the performance or characteristics of the transportation system, including its effect on the nation.* An outcome is typically the cumulative result of actions of many parties throughout the transportation enterprise, and is very often affected by factors external to the organization.

Impacts –*a level of consequence even broader than outcomes.* This relates outcomes to changes as perceived by users and providers of transportation, and the society as a whole. Impacts can have a long time frame and be difficult to quantify: they can include both beneficial and adverse effects. Table V-1 presents several illustrative examples to clarify these concepts.

Performance measurement requires an assessment of the degree to which outputs – in this case, R&D results – meet the needs and expectations of the "customer" – the entity for whom those results were created. In many cases, DOT research organizations are responding to stated mission-related needs of their Operating Administration. Examples include equipment and system improvements needed by the FAA and U.S. Coast Guard to perform their functions, research and analysis to guide how regulatory responsibilities are met, and studies to guide and support policy decisions. In R&D directed more specifically at advancing the system in general, such as improvements in highway construction materials and processes or the application of information technology to transportation operations, the customers for R&D programs include those people and organizations involved with the total transportation enterprise: state and local governments, providers of transportation services and equipment, shippers and consignees, and individual travelers.

Table V-1. Illustrative Examples of Outputs, Outcomes and Impacts for DOT R&D

R&D OUTPUT	INTERMEDIATE OUTCOME	OUTCOME	IMPACT
Consensus on Information Infrastructure, National Architecture and Standards	Guidance to state and local implementers	Interoperable and consistent national system; faster implementation	Reduced highway congestion, greater safety, better system performance
Operational NEXRAD weather radar technology	Widespread deployment of improved weather radar	Reduced air traffic delays and accidents due to weather conditions	Improved aviation system safety, efficiency and service levels
Available new technologies for marine search & rescue	Deployment of improved search & rescue tools	More effective search and rescue activities	Improved marine safety, Additional lives saved
Increased technical understanding of motor vehicle crashworthiness and biomechanics	Regulatory crashworthiness standards	Reduced injuries and fatalities in highway crashes	Improved highway safety, Additional lives saved
Available alternate-fuel buses and operating understanding of them	Purchase and deployment of new buses by transit agencies	Reduced air pollution from bus operations	Improved air quality in urban areas

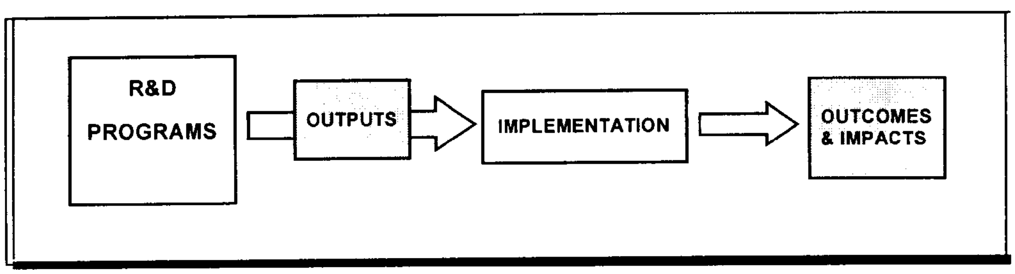
B. R&D and the DOT Annual Performance Plan

As required by GPRA, the Department has prepared the FY1999 *Annual Performance Plan*, based on the *DOT Strategic Plan*, that defines the performance indicators and goals – the measures and targets – that will be used to judge progress in advancing the nation's transportation system. The *Annual Performance Plan* will serve as a link between the Department's strategic goals, annual goals, and the DOT budget program activity structure. It includes a basic set of system-level indicators that DOT will use to measure progress toward its goals in FY1999; these indicators provide the starting point for development of performance measures for long-term outcomes and impacts.

Research, development and technology activities pose a special challenge with regard to performance measurement. They are generally components of broader programs directed toward specific mission responsibilities and the achievement of the DOT strategic goals. However, realization of those goals ultimately depends in large part on many factors that can be distant from the underlying research. Further, in the transportation world, federal activities are generally only a part – often a small part – of achieving final outcomes. Much of the responsibility for implementation falls to the private sector and state and local public agencies. Moreover, final consequences are determined largely by the actions and choices of transportation system users, providers and other affected parties. Finally, outcomes are likely to be very distant in time from the research that contributes to them. The relationship between R&D and societal impacts is suggested in Figure V-1.

In spite of these difficulties, it is quite possible to apply performance-oriented management processes to DOT research programs and to incorporate R&D activities into the broader framework of the Annual Performance Plan. The approach being taken by the Department in this endeavor is described in the remainder of this chapter.

Figure V-1. Relationship between R&D and Outcomes



C. Other Measures of Success

GPRA provides an important and useful framework for managing R&D and assessing its value, but it is focused primarily on the degree to which specific budget items have achieved their expected results. The Department's research and technology activities, singly or aggregated, can be characterized and evaluated in numerous other ways that respond to different basic questions. The nature of transportation research as an enabling element, rather than an end in itself, imposes an inherent uncertainty on any attempt to measure success and ultimate impacts, but meaningful results can be obtained. At the project or program level, it is highly appropriate to consider the *efficiency* of a particular research effort – the degree to which minimal resources and/or minimal time were required to meet the objectives of the work with a high quality effort.

Particularly for exploratory research, and for R&D activities in the aggregate, one can also qualitatively assess *effectiveness*: the degree to which investment, policy, regulatory and operational decisions are affected by the research, and viable new options and solutions are created and characterized.

These two notions – efficiency and effectiveness – can be combined in seeking to assess the cost-effectiveness of research, which requires the ability to quantify potential impacts in economic terms. The ultimate economic impacts of R&D often are far in the future and depend on many externalities and unknowns As a result, only rough estimates of cost-effectiveness are likely to be possible in the near term.

When assessing R&D outputs and intermediate outcomes, the focus is on satisfying the expectations of the "direct" customers: the entity that requested the work, the one to whom the research product will be delivered, or the party that takes the next step in implementing or applying the results. But from a broader perspective, transportation has a significant impact on the nation as a whole by playing a pivotal role in economic development, productivity and global competitiveness. The performance of the transportation system shapes the level of personal mobility and the quality of life of virtually everyone. Thus, the whole society is ultimately affected by the outcomes and impacts of R&D, and in this sense can be seen as a customer. It is this "customer" that is being considered in assessing the degree to which research outcomes and impacts support National and Departmental strategic goals. Measures of these impacts are typically indicators of overall transportation system performance, such as number of fatalities, degree of congestion, and availability and cost of services. Table V-2 suggests a set of candidate measures relevant to the long-term impact of R&D on the nation's transportation system for each of the DOT strategic goals. However, the linkage is not direct; many factors in addition to R&D affect changes in these indicators.

D. Application of Performance Measurement to R&D

Performance of R&D should primarily be assessed on the basis of its direct output – how well and efficiently it is performed -- and the degree to which it meets the needs of the programmatic function it is supporting. In compliance with GPRA, the following general approach has been developed for application at the level of R&D projects:

1. **Definition of Customer(s)**: definition of the direct customer(s) and primary stakeholders – entities with a strong and active interest in the research itself, or in the downstream outcomes associated with it.

2. **Definition of Goals**: delineation of explicit goals for the research – what the customer expects to get at the end of the measurement period. These goals are to have a clear link to the overall program and organizational goals defined by the Department's *Strategic Plan.*

Table V-2: Suggested Impact-Based Performance Measurements for Transportation

Strategic Goal	Impact-based Performance Measure
1. SAFETY	• Reduce speeding-related fatalities 5% by 2000. • Reduce alcohol-related traffic fatalities from 17,000 (1996) to 11,000 (2005). • Reduce motorcycle-related fatalities and injuries 5% by 2000. • Reduce highway fatalities and injuries 20% by 2008. • Reduce child occupant fatalities 15% by 2000 and 20% by 2005.
2. MOBILITY	• Provide access to transportation services for all segments of the population within 10 years.
3. ECONOMIC GROWTH AND TRADE	• Double the dollar value of transportation-related exports (vehicles, systems and technologies) within 10 years and triple it within 20 years. • Reduce the cost to transport goods and freight by at least 25% within 10 years and 50% within 20 years. • Reduce the time to transport goods and freight by at least 25% within 10 years and 50% within 20 years.
4. HUMAN AND NATURAL ENVIRONMENT	• Reduce transportation vehicle emissions by a factor of three) within 10 years and a factor of five within 20 years. • Reduce the noise of future transportation vehicles compared to today's inventory by a factor of two within 10 years and a factor of 4 within 20 years.
5. NATIONAL SECURITY	• Decrease transportation service disruptions due to natural disasters, terrorism, system failure or other causes by a factor of 5 within 10 years and a factor of 10 within 20 years

3. **Definition of Performance Measures**: consultation with customers and primary stakeholders to identify the performance measures by which attainment of their goals for the research can be judged and the means by which they will be evaluated. Major categories include: efficiency, effectiveness, scientific and technical quality, and customer satisfaction with the results. Possible specific performance measures depend on the topic of the research effort and its application, but could include one or more of the following examples:

- % improvement in accuracy
- % improvement in maintainability
- % improvement in reliability
- % increase in capacity
- % increase in energy efficiency

- % increase in speed
- % increase in strength
- % reduction in emissions and/or waste products
- % reduction in life-cycle costs

The way in which DOT's R&D contributes to outcomes and to national goals is primarily through the organizations and programs supported. The terms by which it is measured thus vary depending on which of the primary DOT roles the R&D supports: operational missions, regulatory functions, or national needs.

R&D to Support Operational DOT Missions. Much of the Department's R&D is in support of DOT programs responsive to specific operational functions embodied in legislation and agency mandates. For example, a substantial portion of the FAA R&D budget is associated with evolution and renewal of the nation's air traffic control. Research also provides a necessary foundation for the wide spectrum of services provided by the U.S. Coast Guard. Measures for R&D contributing to these roles would logically be based on aviation mobility (e.g., number of traffic-related delays per 100,000 flight operations) and marine safety (e.g., number of recreational boating fatalities.).

R&D to Support DOT Regulatory Functions. Many other DOT responsibilities, primarily concerned with safety, involve development and promulgation of regulations, standards and specifications. NHTSA's motor vehicle regulatory process, for example, requires research to understand crash causes, identify and assess alternative approaches to their elimination or mitigation, and economic and other adverse impacts on affected parties. In addition, rigorous cost-benefit analyses, assure that regulations or standards are warranted, and establish that the proposed approach is the most cost-effective. R&D can also foster the development of tools and procedures to reduce costs borne by the government, and for the affected parties in certification, inspection and enforcement activities associated with regulations. A possible measure, reflecting the success of R&D underlying a regulatory program, for example, might be the number of hazardous material pipeline failures.

R&D Directly Responsive to National Needs. A large portion of the Department's research is primarily intended to bring about substantial technical improvements by direct stimulation of significant innovation in the transportation enterprise, rather than through mandated functional responsibilities. For example, the Department is extensively involved in guiding and shaping public investment in the transportation infrastructure through trust fund grants. More than $75 billion is spent annually by all levels of government on maintenance and construction of highways: about one-fifth of this amount is federal funds. R&D that reduces the cost and extends the performance and lifetime of roadways and other transportation infrastructure can be a very worthwhile investment.

DOT research and technology initiatives can play a significant part in stimulating and accelerating activity in the private sector, resulting in major innovations in transportation. Although development of advanced transportation technology and improved operations is largely the responsibility of non-federal government entities and the private sector, focused federal investment in research, development, testing, evaluation, and prototype deployment can have significant impacts. This is particularly true when market-driven R&D efforts are delayed by technological and other uncertainties or institutional impediments.

Just as in the case of research in support of specific DOT organizations and operational missions, the management and technical quality of specific outputs remains key for near-term (e.g., annual GPRA) performance measurement. However, these activities are large programmatic initiatives conducted for a very broadly defined "customer": the transportation enterprise and the nation as a whole. The "customer needs" in these cases are inherently embodied in the DOT strategic goals, which thus become the focus of performance measurement. This shifts the emphasis from outputs to intermediate outcomes – closer to the final impacts, but requiring a substantially longer period to become manifest and allow substantive assessment.

For example, judgement of the performance of program to develop technical standards and a national architecture for application of information technologies to road traffic management and operations would initially have to be based on technical quality of the process and the standards. However, the real value of the work will be much more accurately reflected in the intermediate outcome after several years: the degree to which program results are being incorporated in system planning and implementation. In addition, at that point a sound basis exists for estimating or predicting potential changes which the innovation will generate in indicators associated with specific strategic goals (e.g., mobility gains, as reflected in annual hours lost to delay through highway congestion).

On a still longer time frame, real outcomes and societal impacts can be assessed, based on actual changes in pre-defined indicators. Many confounding factors necessarily blur the precision of the link between research and final results, but overall judgments are generally possible. For example, the introduction of seat belts, airbags and enhanced vehicle crashworthiness – based on extensive federal and private research and development – have clearly had a dramatic and quantifiable impact in decreasing the automobile fatality rate and crash injury severity over the last two decades. However, this example also illustrates the complexity of identifying the various elements and programs involved in achieving the outcome in order that the relative role of each can be assessed.

Identification of transportation system indicators that best characterize progress toward DOT strategic goals is a key element in the Department's Annual Performance Plan. Quantitative linkage of these indicators to R&D projects may not be feasible in the near-term. However, it should generally be possible to identify the manner in which the research is expected to achieve an improvement, and estimate the magnitude of this impact.

Many of the quantifiable characteristics of the performance of the U.S. transportation system can affect multiple strategic goals. For example, congestion has an impact on every goal. Table V-3 suggests the relationship among the Department's five strategic goals and major transportation system performance categories for which indicators exist or could be devised for specific modal, functional or market subdivisions.

Table V-3. Transportation System Performance Categories in Relation to DOT Strategic Goals.

(X suggests a relationship; XX suggests a strong relationship)

Transportation System Performance Categories	SAFETY	MOBILITY	ECONOMIC GROWTH & TRADE	HUMAN & NATURAL ENVIRONMENT	NATIONAL SECURITY
Safety	XX	X		X	X
Security	XX		X	X	XX
Capacity	X	XX	XX	X	X
Cost	X	XX	XX	X	X
Energy Efficiency		X	XX	XX	X
Environmental Impacts			X	XX	
Congestion & Other Delays	X	XX	X	X	XX
Availability & Accessibility		XX	XX		XX
Trip & Delivery Time	X	XX	XX		X
Reliability and Robustness	X	XX	XX		XX
Flexibility and Adaptability	X	XX	XX		XX
Ease of Use & Seamlessness		XX	XX		XX

Chapter VI: Implementation Issues and Incentives

The ultimate implementation of the many DOT R&D programs will depend most of all on their acceptance by the users, as well as the operators and maintainers of transportation systems within the U.S. Implementation will not proceed smoothly unless these groups perceive that the new capabilities will clearly make transportation more efficient, more reliable, more available and less costly, at no sacrifice to safety and traveler privacy. This chapter addresses efforts by DOT to insure that these conditions are met with R&D products that are of high quality, quickly and easily installed, well understood by the public, and operated and maintained by a well trained workforce. The Chapter has two parts:

- issues as seen by the stakeholders, and
- addressing the issues that may impede R&D implementation.

A. Issues as Seen By the Stakeholders

There are two major groups of stakeholders that will be significantly affected as the new R&D products are implemented in the transportation system. The first, and largest group, are the users; the second group are the service providers, infrastructure owners, and manufacturers in the transportation system. Each of these two groups may have different perspectives, even among themselves, on what they would like to see the research accomplish.

(a) *The Transportation User Stakeholders*

The user category includes primarily individual private vehicle drivers, passengers, and shippers and recipients of freight. There are an almost infinite variety of user reactions to the new R&D products. Many of them will be positive, but there could be concerns that will slow down their implementation. The users may worry about the invasion of their privacy that might occur as new navigation, information and communications advances permit their travel to be monitored continuously. (This concern has already been expressed during recent attempts by the law enforcement community and others to implement software encryption keys that are controlled by a central agency.)

Automobile drivers may also feel that the automation of traffic management may take away their ability to control their own situation on the road. They might have an averse reaction to collision avoidance systems if these systems do not have extremely low false alarm rates. The transportation user may also have concerns that automation will produce features that will be distracting or difficult to understand and could result in a higher risk of an accident, as the use of cellular phones while driving is beginning to

reveal. This may be especially important during the lengthy transitions to new capabilities when they exist in some vehicles and not in others.
The implementation of ITS features in road vehicles will require such components as: a position location system; a Geographical Information System (GIS); a digital radio transmitter/receiver; and short-range obstacle sensors. Although the size and cost of these components are going down rapidly, their purchase price may be too high for some car buyers, particularly if the automobile manufacturers do not produce them in large numbers.

The implementation of ITS in the fleet of vehicles on the nation's highways will be an evolutionary process. Systems are available today that utilize GPS signals for the purpose of navigation and crash notification. There are other systems available that use short range communication for purposes of automated toll collection. In the near future, it is expected that Adaptive Cruise Control systems that utilize forward looking radar or laser sensors will be available. These systems will be followed in the future by a nationwide capability of automatic crash notification and autonomous crash avoidance systems that address rear-end, lane change, and some types of road departure crashes. Vision enhancement systems that utilize improvements in infrared detection capability will help drivers avoid pedestrians and animals at night. As infrastructure capability becomes available, fully cooperative systems that help highway vehicles safety negotiate intersections and railroad grade crossings will become available.

Even if user concerns appear to be a minority view, it will still be important to address them before the R&D products are introduced. In the ITS program, FHWA has already begun this process through user acceptance research. Long term user acceptance studies can demonstrate that the products of research work smoothly and produce reliable benefits. Citing associated advantages such as increased fuel efficiency, safety, and reduced air and water pollution and noise may also help to allay these concerns.

(b) *The Transportation Infrastructure Owner, Service Provider and Manufacturer Stakeholders*

R&D products will have different impacts on different types of federal and private sector transportation service providers. Among these are: FAA air traffic controller, maintenance and aviation certification personnel; U.S. Coast Guard personnel; employees of commercial airlines; railroad locomotive engineers and dispatchers; bus and truck drivers; operations, construction and maintenance personnel; and the public safety community.

The implementation of "free flight", for example, will change the roles of airline pilots and dispatchers, and particularly those of air traffic controllers. Today's en route controllers provide aircraft separation along regular air routes that they have worked with often for many years. Thus, many of them have developed an ingrained knowledge of backup procedures, such as workable holding patterns, that can be implemented in the event of system failures. Preferred routes, a precursor to "free flight" status that deviates from the regular routes but still maintains a train of aircraft to a known merge point, are provided to airline pilots today. "Free flight" will increase the number and variety of preferred routes and extend the lengths of the merge points across more en route centers from the aircraft's departure terminal (airport) area to its destination terminal area.

In an effort to begin the implementation of "free flight", the FAA has collaborated with the airlines and the general aviation community to develop a new operational "Free Flight Phase One" concept, which will be demonstrated in aircraft operations in Alaska, and other airspaces. The continuation of demonstrations in much higher density en route air spaces within the continental U.S. will present a bigger challenge. To help facilitate this transition, the FAA is also developing improved airborne and ground collision avoidance and resolution systems. For example, improvements in the Traffic Management System and the new Center/Terminal Automation System (CTAS) will address the necessary airport capacity increases and the less rigid routes and arrival times for aircraft under "free flight".

Today's in-trail separations of arrival aircraft to avoid wake vortex problems may be reduced to some extent through future research that improves the prediction of the vortex intensities and directions. However, factors such as competition for land use and the public resistance to aircraft noise in urban areas may prevent significant capacity increases at the major existing U.S. airports. The FAA has already started research into low noise aircraft, but this is only a partial solution. One potential intermodal response to capacity and noise considerations is to expand traffic at smaller 'feeder' airports that are connected to the urban areas by high speed rail transit.

There have been many types of ITS improvements and demonstrations throughout the U.S. in recent years. The operators of interstate trucking companies, package delivery services, railroads, and public transit have welcomed ITS advances mostly because of their existing large investments in their vehicle fleets and the efficiencies that can result. The impediments to full-scale implementation occur when cities and towns cannot afford the cost of installing the ITS system infrastructure, even if the ultimate result is increased efficiency and lower operating costs.

The public safety community, including law enforcement, fire departments and emergency medical services, are an example of groups that face difficulties in implementing certain ITS improvements, particularly because they have a large inventory of older wireless communication equipment and vehicles without ITS capabilities. The older wireless equipment has 25 kilohertz (KHz) bandwidths that are inefficient when compared with 12.5 KHz bandwidths available on the most recent equipment, and even lower 6.25 KHz bandwidths that will be available in the future.

Moreover, this equipment uses numerous different spectrum bands that are not interoperable. As mentioned in Chapter III, the U.S. Coast Guard has initiated a long term SBIR program to design a prototype interoperable radio that may alleviate this situation. But until the program succeeds, this interoperability problem and the fact that ITS requirements for additional digital wireless spectrum may lead to communications congestion, becomes more pronounced, given the growing demands for spectrum by commercial services.

In an effort to protect the available spectrum for these users, DOT formed a Public Safety Wireless Advisory Committee to present the community's case to the FCC. The Committee recommended reducing the receiver channel spacings ("refarming") down to 6.25 Khz and building cross-band receivers to use other parts of the spectrum if the existing spectrums became too crowded or were auctioned off. DOT will continue to monitor this situation carefully in the future. Regardless of the solution, however, the public safety community cannot easily afford changes to their current wireless radios. More importantly, the radio manufacturers also have existing inventories of this equipment and are reluctant to produce a newer type of radio unless a much larger market emerges. This is an example of a problem that could be solved if the costs of the needed equipment were significantly reduced by mass production.

Given the many different types of equipment and systems, FHWA has developed an ITS architecture that stresses equipment interoperability standards. The FRA is also researching interoperable and standardized communications networks for railroads, and federal efforts to develop specifications for vehicle construction are being considered. But establishing standards with the broad consensus of industry will be a very lengthy process. This is particularly true for the telecommunications industry, where a continuing international debate over new wireless radio modulation technology is ongoing.

The research effort to provide micro-scale weather data and forecasts to motorists will benefit from the planned fusion of data from many more sensor sources. If this can be successfully achieved, it might be accepted as a standard automobile feature that drivers and passengers would pay a small amount (e.g., a local phone call) to use. The charge for the weather information, tailored to the vehicle's location and route, might be an incentive for the telecommunications industry to provide the service.

Liability issues that industry may have to face with the introduction of new R&D products will remain an important consideration in the future. Some industries may regard the new products as untried solutions unless they have many years of testing. For example, the traditionally conservative railroad industry has been cautious about the introduction of improved materials technology in the rail system. Similar liability questions might also arise if installed smart structures or other advanced materials were to fail.

B. Paving the Way for R&D Implementation

The vast majority of transportation programs receiving federal assistance are managed by the recipients of these grants and sub-grants, and not directly by DOT itself. These recipients include state, tribal, county, and city governments agencies; regional and municipal authorities; special districts; and academic and research institutions. The range of issues these recipients must confront has also significantly expanded beyond the earlier focus on physical infrastructure construction to such new goals as mitigating congestion, improving air quality, and effectively implementing advanced sensing, computing, and communications technologies.

Unfortunately, experience has shown that Government contracting procedures can significantly hinder the adoption of advanced technologies. Procurement procedures for state and local governments under grants and cooperative agreements that use federal funds are set forth in title 49, Code of Federal Regulations (49 CFR, Part 18), "Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments". In addition, federal-aid funds are governed by title 23. Under all but exceptional circumstances, procurements are to be conducted in a manner providing full and open competition. Contracts awarded under any federally-funded program must also comply with existing legislated financial, labor, and environmental criteria. The useful purpose of many of these practices is to reduce risk, protect investments, ensure accountability, and advance related social and economic goals. However, these same practices can also discourage technological innovations and lead to higher actual life-cycle costs for a product.

Recognizing this concern, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 encouraged the adoption of contracting procedures that promoted advanced technologies, as well as experimentation with various new means of financing projects. After studying the Department's contracting and acquisitions procedures, the Acquisitions, Reengineering, and Realignment Task Force in 1994 recommended ways to streamline the current system. In January 1995, President Clinton announced the "Partnership for Transportation Investment." Also known as "Innovative Financing," this new process allows many of the existing restrictions and requirements on the use of federal funds to be waived and gives local decision makers greater flexibility in preparing a total funding package for a transportation project. The primary goal is to assist public agencies to leverage their funds by attracting additional investments from other public and private sources and enable projects to be initiated more quickly than under traditional financing procedures. A number of recommendations designed to leverage additional investments from non-DOT sources and to improve short-term cash flows have already been adopted.

There are several existing R&D and demonstration programs that do allow for greater flexibility. FHWA and FTA, for example, encourage grant recipients to participate in the National Cooperative Highway Research Program (NCHRP) and the Transit

Cooperative Research Program (TCRP), respectively. These programs allow for the development, testing and demonstration of new construction technologies, materials, and processes.

In addition to contracts, DOT employs other, more flexible procedures to leverage its limited R&D resources. These include Broad Agency Announcements, grants to research institutions, and Cooperative Research and Development Agreements (CRADAs). The Department has also benefited considerably from the results of long-standing cooperative research programs with universities, industry and professional associations.

DOT has increasingly been using such tools as the Internet to ease and expedite many of the government's contracting and grant procedures by posting information ranging from university research grants to contract solicitations and awards. For example, SBIR Program Solicitations, Requests for Proposals and Commerce Business Daily notices are available on the Department's World Wide Web (WWW) sites.

There have also been reforms to the laws governing federal procedures. The Federal Acquisition Streamlining Act of 1994 and the National Defense Authorization Act for Fiscal Year 1996 were both meant to streamline the federal procurement process. This legislation gives agencies expanded authority in such areas as awarding multiple-contractor task-order and delivery-order contracts, and raises the dollar value threshold for the application of certain legal restrictions on acquisitions procedures. It would also be useful to explore other innovative transaction mechanisms being used by agencies such as DARPA and the Department of Energy for possible application within transportation.

Additional innovative practices suggestions include: further encouragement for private/public partnerships and State Infrastructure Banks, electronic payment technologies, design/build contracting, life-cycle cost evaluation, negotiated bid awards, and the award of R&D funds to consortia to promote the early deployment of technological innovations.

Thus, it is evident that the federal government and the Department of Transportation are taking actions to reduce existing statutory and procedural restrictions on R&D activities and the application of advanced technologies that emerge from this process to the nation's transportation system.