Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations

March 2002

U.S. Department of Transportation
Federal Railroad Administration

U.S. Department
of Transportation
**Federal Railroad
Administration**

Administrator

1120 Vermont Ave., NW.
Washington, DC 20590

Dear Reader:

I am pleased to present the Federal Railroad Administration's Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations. The plan outlines a vision for the future of railroads and the technologies needed to support them.

The Federal Railroad Administration has coordinated this plan with a wide variety of user groups, both within and outside the Department. These included other Operating Administrations within the Department, the Association of American Railroads, the American Short Line and Regional Railroad Association, the American Public Transportation Association, the Railway Progress Institute, the Transportation Research Board, labor unions, railroads, States, suppliers, universities, and individuals. Input from each of these groups helped form the basis of the plan.

We view work on this plan as a continuing effort. We intend to make periodic updates to take into account evolving technologies as well as changes in the physical and institutional aspects of the freight, intercity passenger, and commuter railroad industries.

Sincerely,

Allan Rutter
Administrator

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AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ADUS	Archived Data User Service
AEI	Automatic Equipment Identification
ALPS	Advanced Locomotive Propulsion System
APCO	American Public Safety Communications Officers
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance of Way Association
ASLRRA	American Short Line and Regional Railroad Association
CTA	Cognitive Task Analysis
DGPS	Differential Global Positioning System
DMU	Diesel Multiple Unit
DOE	Department of Energy
DTA	Damage Tolerance Analysis
ECP	Electronically-Controlled Pneumatic [brakes]
EIS	Environmental Impact Statement
EMF	Electromagnetic Fields
EMR	Electromagnetic Radiation
EMS	Energy Management System
EO	Executive Order
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Facility for Accelerated Service Testing
FEEST	Freight Equipment and Environmental Sample Test
FEM	Finite Element Modeling
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GIS	Geographical Information System
GPR	Ground Penetrating Radar
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRMS	Gage Restraint Measurement System
GWEN	Ground Wave Emergency Network
HAL	Heavy Axle Load
Hazmat	Hazardous materials
HRI	Highway-Rail Intersections
HSR	High-Speed Rail
IDEA	Ideas Deserving Exploratory Analysis
ISTEA	Intermodal Surface Transportation Efficiency Act
ITCS	Incremental Train Control System

ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LRV	Light Rail Vehicle
MBTA	Massachusetts Bay Transportation Authority
MEMS	Micro-electro-mechanical Systems
MIT	Massachusetts Institute of Technology
MUTCD	Manual of Uniform Traffic Control Devices
NAFTA	North American Free Trade Act
NAJPTC	North American Joint Positive Train Control Program
NDE	Non-Destructive Evaluation
NDGPS	Nationwide Differential Global Positioning System
NEC	Northeast Corridor
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Standards and Technology
NSTC	National Science and Technology Council
NTSB	National Transportation Safety Board
PDD	Presidential Decision Directive
PEIS	Programmatic Environmental Impact Statement
POD	Probability of Detection
PRESS	Passenger Rail Equipment Safety Standards
PTC	Positive Train Control
PTSD	Post-Traumatic Stress Disorder
RAIRS	Rail Accident/Incident Reporting System
R&D	Research and Development
RD&D	Research, Development, and Demonstrations
RDTF	Rail Defect Test Facility
RPI	Railway Progress Institute
RSAC	Railroad Safety Advisory Committee
RSPA	Research and Special Programs Administration
SAIC	Science Applications International Corporation
SBIR	Small Business Innovative Research
STP	Strategic Traffic Planner
TEA-21	Transportation Equity Act for the 21st Century
TFT	Track Forces Terminal
TRB	Transportation Research Board
TTC	Transportation Technology Center
TTCI	Transportation Technology Center, Inc.
TTP	Tactical Traffic Planner
UHF	Ultra High Frequency
USDOT	United States Department of Transportation
VHF	Very High Frequency
VIS	Video Imaging System
VTI	Vehicle Track Interaction
WOR	Work Order Reporting
Y2K	Year 2000

Executive Summary

The Federal Railroad Administration (FRA), at the request of the Senate Appropriations Committee, prepared this *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations* ("Five-Year Plan for RD&D"). It is being published at a time of rapid changes in technology and in the structure and nature of the railroad industry. The Five-Year Plan for RD&D includes projects funded under three programs: Railroad Research and Development, the Next Generation High-Speed Rail Technology Demonstration Program, and the Magnetic Levitation Technology Deployment Program.

Elements for these programs were developed based on historical risk and accident analysis, strategic review of industry trends, and a review of current research, development, and demonstration projects promising significant results. Goals, and activities for achieving the goals, were established around each of these areas. The Railroad Research and Development Program includes ten program elements as follows: railroad system issues (safety, security, environment), human factors, rolling stock and components, track and structures, track/train interaction, train control, grade crossings, hazardous materials, train occupant protection, and R&D facilities and equipment. The Next Generation Technology Demonstration Program includes four program elements: train control demonstrations, high-speed non-electric locomotives, high-speed grade crossing protection, and track and structures technology. The Magnetic Levitation Technology Deployment Program has initiated a competition to plan and demonstrate a magnetic levitation (maglev) transportation system to demonstrate the technology in revenue service in the United States. (The sequence of the programs, and of the program elements within the programs, used in this report does not represent a prioritization of the programs or the program elements.)

RAILROAD TRENDS

In 2000, the entire United States railroad system encompassed 660 railroads, 220,000 miles of track, 20,000 freight locomotives, 8,800 passenger locomotives/coaches, 1,300,000 freight cars, and 265,000 employees. The freight railroad industry's share of the ton-miles of intercity freight grew from less than 38 percent in 1990 to more than 40 percent today. The demands on this system are continuously growing, and changing technologies provide the opportunity to improve system effectiveness and efficiency. For the first time since World War II, some railroads have capacity constraints on certain lines. Meanwhile, Amtrak, the intercity passenger railroad, has invested in electrification between Boston and New Haven and new, electrified Acela Express train sets that provide service at speeds up to 150 miles per hour on the Northeast Corridor between Washington and Boston. In addition, a number of States are proposing light rail, commuter rail, and high-speed rail passenger corridors on existing rail lines.

For railroad safety, the number of casualties decreased from 20,400 in 1993 to 12,580 in 2000. During the same period, fatalities declined from 1,279 to 937 and the number of injuries fell from 19,121 to 11,643. Of the total number of reported railroad incidents in 2000, 38 percent were ascribed to human factors causes, 36 percent to track defects, 12 percent to equipment failures, 2 percent to signals, and 12 percent to miscellaneous causes. These percentages were virtually unchanged over the past five years.

TRENDS IN RESEARCH, DEVELOPMENT, AND DEMONSTRATIONS

The highest priority of the FRA is the safety of the railroad system. Despite the improvement in railroad safety, there are still too many railroad accidents of all types. With a goal of significantly reducing accidents and casualties, the FRA is aiming its research activities at addressing safety issues in each and every technological area that can reduce both the probability of and severity of accidents. The FRA addresses safety concerns in all phases of railroad operations—through research, development, and demonstrations; regulation and enforcement activities, and financial assistance—to ensure that railroads in the United States continue to be among the safest in the world.

FRA's Five-Year Plan for RD&D reinforces activities addressing the need for a strategic approach to railroad research and technology. Strategic plans prepared by the National Science and Technology Council, the U.S. Department of Transportation, and FRA established the foundation for the development of this Five-Year Plan for RD&D. These strategic plans are the product of extensive industry and government coordination and consultation.

Digital communication technologies are revolutionizing not only the telecommunications industry, but the railroad industry as well. Intelligent Transportation Systems (ITS) for highways and mass transit are based on these technologies, as are the new air traffic control and maritime vessel tracking systems. The military services, the major parcel delivery companies, pipeline operators, and police, fire, and ambulance services also use these technologies. The FRA and the railroad industry are working on the development of Intelligent Railroad Systems that would incorporate the new digital communications technologies into train control, braking systems, grade crossings, defect detection, and into planning and scheduling systems as well. Intelligent Railroad Systems will improve the safety, security, and efficiency of freight, intercity passenger, and commuter railroads. Work on certain of the components for which Federal support is deemed appropriate will be carried out under this Plan.

At the request of the Senate and House Appropriations Committees, the FRA contracted with the Transportation Research Board (TRB) to establish a committee to conduct a peer review of both the R&D and Next Generation Programs. This committee includes representatives of the various States, railroads, labor unions, universities, financial institutions, and research organizations. At the urging of this committee, FRA has developed a structured process to identify safety research areas and select specific safety R&D projects for funding. The approach consists of five logical steps that have been applied to the Grade Crossing and Track and Structures R&D program elements and are reflected in this Five-Year Plan for RD&D. The steps are as follows:

1. Review of historical and potential risk in the railroad industry.
2. Conduct failure analysis.
3. Survey government and industry countermeasures and R&D requirements.
4. Develop and rate individual projects.
5. Select projects and assign to program areas.

Subsequently, as new information becomes available about sources of safety hazards, the logical steps may be followed for specific types of safety hazards to add to the list of potential safety R&D projects.

The FRA manages the programs described in this Five-Year Plan for RD&D with a small staff of program managers. Some of the research and development is carried out at FRA's Transportation Technology Center (TTC) near Pueblo, Colorado; some is carried out or administered by the John A. Volpe National Transportation Systems Center in Cambridge, Massachusetts. The remainder is carried out through grants, cooperative agreements, and competitively awarded contracts with universities, railroads, railroad suppliers, consulting engineers, government agencies, national laboratories, and other organizations with appropriate technical expertise. The Next Generation High-Speed Rail Technology Demonstration Program relies upon cooperative agreements with States and manufacturers to execute the various demonstration projects. The Maglev Technology Deployment Program is a cooperative effort with cost sharing from State or regional authorities and private sector participants.

FRA's Office of R&D conducted a managerial self-assessment in July 2000, using the seven Baldrige Award criteria: leadership, strategic planning, customer and market focus, information and analysis, human resources focus, process management, and business results. It graded itself relatively high in the categories of organizational leadership, strategy development and deployment, customer and market knowledge, work systems, employee well being and satisfaction, and supplier and partnership processes. Categories calling for improvement were customer satisfaction and relationships, measurements of organization performance, employee education, product and service processes, and support processes. FRA's Office of R&D will continue to use the Baldrige Award criteria for self-assessment as an integral part of its planning process.

FRA recognizes the importance of strategic workforce planning to ensure that the human resources are available to accomplish the mission of this Five-Year Plan for RD&D. FRA is undertaking a seven-step strategic workforce planning process for the Office of Research and Development:

1. Build leadership commitment.
2. Develop a profile of current projects and workforce.
3. Link the project base to strategic goals.
4. Collect data on future resource requirements.
5. Identify workforce-planning objectives and analyze the issues potentially impacting our ability to meet them; develop strategies and plans.
6. Evaluate workforce planning process and results.
7. Revise process/results based on findings.

The strategic goals and the strategies laid out in this workforce plan will provide the guidance needed to permit the development of a coherent and compatible plan to retain, hire, and develop the necessary workforce.

RAILROAD RESEARCH AND DEVELOPMENT PROGRAM

FRA's R&D Program primarily supports FRA's safety regulatory processes, but also provides support to railroads involved in the transportation of freight, intercity passengers, and commuters; railroad employees and their labor organizations; and railroad suppliers. The TTC provides the infrastructure necessary to conduct experiments and to test theories, concepts, and other technologies in support of the R&D program. The TTC is built on land leased from the State of Colorado and is operated under contract by Transportation Technology Center, Inc. (TTCI), a wholly-owned subsidiary of the Association of American Railroads (AAR). The FRA, other government agencies, the railroad industry, individual railroads, transit operators, suppliers, and foreign organizations, all use TTC.

Railroad safety depends on the reliability of people, as well as infrastructure, equipment, and control systems. Railroading is known to operate in a hostile, unforgiving physical environment. Railroad operating workers need knowledge, training, tools, and alertness to do their jobs properly and insure the public's as well as their own and their coworkers' safety. Railroad infrastructure has many elements, including soil in embankments, ballast, ties, rail, rail fastening devices, turnouts, bridges, and tunnels, that must be properly designed, installed, used, maintained, inspected and secured if railroads are to be operated safely.

Similarly, railroad equipment has many components, including wheels, bearings, axles, trucks, springs, brakes (both air, and the new electronically-controlled), under-frames, draft gear, and couplers. All components must also be properly designed, installed, used, maintained, and inspected if railroads are to be operated safely. Train control systems, which have historically been very reliable but still enable a human being to make a mistake and cause an accident, need to be upgraded to prevent the possibility of human error from causing accidents.

Rail transportation of passengers and hazardous materials present situations that require special attention to ensure that a high level of safety and security is maintained. Perhaps the greatest safety risk of all for railroads occurs at those locations where railroads intersect with streets and highways. All these topics receive specific attention in this Five-Year Plan for R&D, which addresses these issues through an appropriate combination of study, analysis, simulation, laboratory testing, and field-testing.

The **Railroad System Issues** program element addresses: (a) contextual research on technological and operational developments within the railroad industry that may influence the need for safety R&D; (b) system safety issues for freight, commuter, intercity passenger, and high-speed passenger railroads, including performance-based regulations; (c) physical and cyber security in the railroad system; and (d) environmental issues related to railroad operations. This program element undertakes research intended to enhance railroad safety from a system perspective, especially for issues and topics not covered by traditional equipment or track-related research initiatives. The physical vulnerability of the U.S. railroad network is of concern, especially in light of the terrorist attacks in New York and Washington in September 2001.

The **Human Factors** program element addresses railroad accidents in two primary areas: Operating Practices and Grade Crossings. Operating practices projects target human factors accidents in yards and terminals and in mainline train operations. Human factors-related grade crossing projects address issues regarding motor vehicle drivers, visual and audio warnings, and crossing gate and light technology to reduce accidents. The human factors program element also provides analytical and technical support to reduce the number of accidents, deaths, and injuries due to human error, and to reduce the rate of railroad employee-on-duty fatalities, injuries and illnesses. The human factors program element uses the "human-centered systems" approach that focuses on human capabilities and limitations with respect to human/system interfaces, operations and system integration. Increased attention to human performance and behavior will reduce crashes, loss of life, injuries, property damage and resultant personal and financial costs.

The **Rolling Stock and Components** program element places emphasis on the development and improvement of equipment defect detection and control via wayside and onboard detection. Such systems promote early defect detection and help prevent derailments due to equipment failure. This program element focuses on a proactive approach to preventing derailments, equipment failure, and undesired emergency brake applications. This approach will involve risk assessment and mitigation, along with support for safety assurance. This program element is expected to fulfill the demands of faster, heavier, and longer trains by extending equipment and material life through early defect detection and advanced material development.

The **Track and Structures** program element provides the analytical and technical basis for the development of safety standards and best industry maintenance, inspection, and operating practices to reduce accidents, deaths, injuries, and property damage related to track and other infrastructure failures. The program will improve analytical and experimental procedures for better understanding the mechanism of fracture development in rail steel under passing loads, improved nondestructive (field) test methods for detecting flaws in rail steel, and improved methods for determining when track is at risk of sudden lateral buckling or of pulling apart from rail longitudinal forces induced by seasonal temperature changes or by tractive or braking forces. The program also addresses advanced inspection technologies to detect track hazards (track bed weakness, wide gage, faulty geometry) well before accidents can occur and the safe load capacity and structural integrity of bridges. Research results are incorporated into FRA Track Safety Standards and railroad maintenance practices. Activities in this program element are coordinated with and complement the Track and Structures demonstration activities in the Next Generation High-Speed Rail Program.

The **Track/Train Interaction** program element addresses the safety implications arising from the dynamic interaction between track and train. The program will: (a) improve analytical and experimental methods for assessing derailment risk due to anomalous interactions of track geometry and railcar suspension systems; (b) provide improved guidelines for rail grinding or lubrication that will facilitate optimum wheel-rail contact and truck steering in heavy load and high-speed situations; and (c) develop a comprehensive computer program for modeling and simulating railway vehicle/track systems, with an emphasis on the dynamic performance of both vehicle and track and their interactions through the wheel/rail interface. The program supports the development of performance-based standards and guidelines for vehicle/track interaction safety and ride quality, and of safety standards and guidelines for transverse wheel and rail profiles.

The **Train Control** program element engages in four types of activities regarding train control: facilitation, risk analysis, testing and evaluation, and development of support systems. To facilitate the deployment of Positive Train Control (PTC) on the nation's railroads, the FRA is serving as lead agency within the USDOT for determining the requirements, requesting funding, and managing the implementation, operation, and maintenance of Nationwide Differential GPS. FRA is undertaking the analyses to evaluate the risks of collisions and overspeed accidents on the corridors that make up the national railroad network, as well as to evaluate the risks of the various technologies that comprise PTC. FRA will undertake the necessary testing and evaluation to confirm the integrity of the various PTC demonstration programs when they become operational, and will establish facilities where further testing and evaluation can be carried out. Activities in this program element are coordinated with and complement the train control demonstration activities in the Next Generation High-Speed Rail Program.

The **Grade Crossings** program element focuses on technical aspects of the highway-railroad intersection. (Human factors aspects of grade crossings are addressed in the Human Factors program element.) This program element addresses evaluation methodologies, visual and audio warnings, motor vehicle and train presence detection, crossing geometry, crossing gate and flashing light technologies, the Intelligent Transportation Systems (ITS) prototype tests, and the development of standards under the National ITS Architecture. ITS offers the potential for deploying low-cost innovative warning systems that may have greater effectiveness than passive warning devices. The risks posed to both highway and rail users have been examined in new risk assessment evaluations. These risk assessments are necessary to develop a more precise understanding of the risks posed by grade crossings and in evaluating proposals to decrease these risks. Research efforts are being coordinated with other Operating Administrations in USDOT, the TRB, and Transport Canada. Activities in this program element are also coordinated with the grade crossing demonstration activities in the Next Generation High-Speed Rail Program.

The **Hazardous Materials** program element includes projects to identify tank car operating and accident environments; to reduce multiple car derailments through the use of improved shelf couplers; to establish use and design parameters for 286,000 lb. gross-weight tank cars; and to prevent unwanted hazmat release due to incorrect relief device design, capacity, and/or setting. Other projects will evaluate and develop improved engineering design mathematical modeling and validation, develop effective inspection methods to ensure continued tank car integrity, including documented reliability and sensitivity for the methods used, and reduce the risk for emergency response personnel by validating damage assessment guidelines for accuracy, timeliness and applicability. Some of the results will provide the basis for FRA inspection and maintenance regulations.

The **Train Occupant Protection** program element carries out research on structural crashworthiness and interior safety of locomotives, and of intercity and commuter rail cars to improve the survivability of rail passengers and crew members in accidents. In addition, system safety and fire protection are addressed. Simulations, laboratory tests, and full-scale fire and impact tests are conducted. The goal of this research is to promote and improve the safety of intercity passenger and commuter rail services.

The **R&D Facilities and Equipment** program element addresses the acquisition, upgrading, and maintenance of FRA-owned facilities and equipment required to accomplish the whole spectrum of railroad research objectives. FRA's research and testing facilities are located at the 52-square mile TTC, which includes laboratories and 50 miles of test tracks for testing a wide range of locomotives, cars, and track structures and components for freight, passenger, transit, and high-speed rail operations.

In addition to the fixed facilities at TTC, FRA owns and operates research cars to support the track research program. The T-16 is capable of collecting track geometry and ride quality data at high speeds, and the T-6 is equipped with the Gage Restraint Measurement System (GRMS) which measures the ability of track to maintain gage to preclude wide gage derailment.

NEXT GENERATION HIGH-SPEED RAIL TECHNOLOGY DEMONSTRATION PROGRAM

The Next Generation High-Speed Rail Technology Demonstration Program ("Next Generation Program") seeks to demonstrate that the public will welcome incrementally upgraded high-speed rail passenger service which provides air- or road-competitive door-to-door trip times between major city pairs with reliable, high quality, cost-effective service.

The Next Generation Program—based on partnerships with suppliers of technology, railroads, and State governments—will be providing a real-world environment for the application of these technologies, preparing the way for a smooth introduction when States are ready to implement their systems, and ensuring that duplication of efforts is minimized. The States that are already implementing HSR incremental upgrade programs are targeting service speeds of 110 to 125 miles per hour for the near future, primarily on existing track also used for freight. The program includes four program elements: positive train control demonstrations, high-speed non-electric locomotive, high-speed grade crossing protection, and track and structures technology.

The **Positive Train Control** program element includes demonstrations of systems suited to maximizing the capacity of railroads to carry a mix of high-speed passenger, commuter, and freight trains with minimal risk of collision and at considerably lower cost than conventional railroad signal and control systems. The positive train control demonstration will result in validated, cost-effective technologies—coordinated with the freight railroad industry—which States will be able to select and implement on emerging high-speed corridors. The effectiveness of prospective train control systems must ultimately be demonstrated over entire corridors, dealing not only with relatively simple, uncongested rural operations, but also with urban rail terminal areas where operations are frequent, complex, and compete for communications spectrum with thousands of other radio transmitters both on and off the railroad property.

The **High-Speed Non-Electric Locomotive** program element will demonstrate a lightweight locomotive that achieves the speed and acceleration capability of electric trains without the expensive infrastructure of railroad electrification. The availability of demonstrated, cost-effective high-performance locomotive technology is an essential precursor for high-speed service on the emerging high-speed corridors. The expected outcome of this program element is a fleet of such locomotives demonstrating high-acceleration, high-speed, and reliable service on one or more corridors.

The **High-Speed Grade Crossing** program element will develop, demonstrate, and evaluate innovative grade crossing warning systems for application on high-speed rail corridors. The objective is to provide nearly the same security as grade separations but at a lower cost. The Sealed Corridor Initiative in North Carolina is representative of projects that could be successfully applied to other high-speed corridors.

The **Track and Structures** program element addresses issues associated with route capacity limitations of existing corridor infrastructure by seeking out and demonstrating innovative, more cost-effective methods to construct new track and structures, and also to seek out and demonstrate components suitable simultaneously for comfortable, high-speed passenger operations and durable enough for frequent, heavy axle load freight operations. This program element will provide validated new technology to permit States and their partners to afford infrastructure investments for adequate route capacity, with satisfactory performance, to implement high-speed passenger service on already-congested freight corridors.

MAGNETIC LEVITATION TECHNOLOGY DEPLOYMENT PROGRAM

FRA was directed by the Transportation Equity Act for the 21st Century to initiate a competition to plan and build a magnetic levitation (maglev) project somewhere in the United States. The authorized Federal funding consists of $55 million for preconstruction planning to identify the most promising project, and up to $950 million for final engineering and construction of the guideway of the one selected project. Of the selected project's total cost, the Federal Government would provide up to $950 million of the funding, and the State or local governments or private entities would provide one-third. To be eligible for construction funding, each project must demonstrate that operating revenues will exceed operating costs, and total benefits will exceed total costs over a 40-year period on a project or corridor basis. Seven projects were selected to receive planning grants in May 1999. In January 2001, the field was narrowed by the selection of two projects by the USDOT for refined planning: one in Pittsburgh, and one connecting Baltimore and Washington. Both projects are preparing site-specific environmental impact statements that will be completed by 2003. FRA expects to select a single project early in FY 2003 and enter into an agreement to provide Federal assistance to design and build the project, subject to appropriations of funds, early in FY 2004.

CONCLUSION

Research and technology development is an ongoing, iterative process that must be both forward looking and flexible enough to address new needs. This Five-Year Plan for RD&D has been developed with industry consultation to meet identified needs of the several parts of the railroad industry—freight, intercity passenger, and commuter. It is flexible enough to address new needs and to take advantage of new opportunities. FRA will continue to: (a) work with all parts of the railroad industry, (b) use its R&D project development and selection process, (c) undertake management self-assessments, and (d) have a peer review program under the auspices of the Transportation Research Board. Changes will be made to the Plan when necessary to meet the needs of the Federal Government, the railroad industry, its employees, its customers, and its suppliers.

Despite record traffic levels in the freight railroad industry and the creation of fewer, larger railroad companies, financial difficulties have caused the large railroads to cut back significantly on their in-house R&D programs and to reduce their jointly funded program carried out through TTCI. Furthermore, Amtrak and the commuter railroads have no surplus funds to spend on R&D. These situations underscore the importance of the FRA RD&D program.

It is difficult to identify specific goals and outcomes for the FRA RD&D program in a five-year timeframe. Only a portion of the projects will be completed within five years, and not all will produce results that can or should be implemented. The rate at which project results will be implemented depends in part on the benefit-cost ratios of the technologies or processes developed in the individual projects, in part on the availability of and competition for capital in the railroad industry, and in part on the rate at which FRA mandates their implementation. The recent improvements in railroad safety are the result of R&D conducted in the 1970's and 1980's along with the sizeable investments railroads made in infrastructure and rolling stock during the 1980's and 1990's. At best, implementation of the results of only a small portion of the projects described herein will have begun five years from now. Effects of the projects described in this plan will begin to show up in railroad safety and efficiency statistics in earnest about ten years from now. This plan describes an RD&D program that will have long-term effects on the U.S. railroad system.

chapter 1.0

Introduction

The highest priority of the Federal Railroad Administration (FRA) is the safety of the United States railroad system, which, in the year 2000, encompassed 660 railroads, 220,000 miles of track, 20,000 freight locomotives, 8,800 passenger locomotives/coaches, 1,300,000 freight cars, and 265,000 employees. The demands on this system are continuously growing, and changing technologies provide the opportunity to improve system safety, security, effectiveness, and efficiency. The FRA addresses safety concerns in all phases of railroad operations—through research, development, and demonstrations (RD&D), development of new regulations, and enforcement activities to ensure that railroads in the United States continue to be among the world's safest. In addition, FRA undertakes projects to stimulate and encourage the deployment of innovative and safe intermodal freight service, light rail and commuter rail services, high-speed rail service, and magnetic levitation passenger service in the United States.

This *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations* ("Five-Year Plan for RD&D") was prepared at the request of the Senate Appropriations Committee, and is being published at a time of rapid changes in technology and in the structure and nature of the railroad industry.

1.1 U.S. Railroad Industry

The changes that occurred in the freight railroad industry over the past seven years have been as radical as any that have taken place in the 175-year history of the industry. There are now only four major freight railroads: Burlington Northern Santa Fe, CSX, Norfolk Southern, and Union Pacific. Together they represent about 90 percent of the business in the freight railroad industry. Mid-sized railroads, such as Kansas City Southern, Guilford Rail System, Montana Rail Link, Florida East Coast, and the U.S. lines of Canadian National and Canadian Pacific, serve regional markets. A large and growing number of short line railroads serving sub-regional and local markets throughout the country have come into being as the large railroads sell off unprofitable branch lines to private operators that have the ability to provide better service at lower cost. A growing number of short lines are being purchased by holding companies, but others are owned by individuals and small businesses, and some are owned by states and municipalities. The structural changes in the railroad industry are occurring as the market for railroad freight transportation continues to reach record levels. Only half of the freight car fleet is owned by railroads; the other half is owned by shippers and private car owners. Profitability of the railroad industry reached an all-time high in 1996, but has declined since the major railroads had difficulties in implementing mergers and acquisitions and as the economy slowed in late 2000 and 2001. The freight railroad industry does not appear as yet to have arrived at a stable institutional structure.

Amtrak, a quasi-public corporation, remains the sole provider of intercity rail passenger service in the contiguous 48 States. The Alaska Railroad, a state-owned corporation, operates intercity rail passenger service in Alaska and is planning to establish commuter service. There are now 19 commuter railroads subject to FRA oversight, ranging from large ones, such as the Long

Island Railroad (LIRR), MetroNorth Railroad, New Jersey Transit (NJT), Southeastern Pennsylvania Transportation Authority (SEPTA), Massachusetts Bay Transportation Authority (MBTA), Northeast Illinois Regional Commuter Railroad Corporation (METRA), and Southern California Regional Rail Authority (SCRRA- Metrolink), to smaller operators such as Vermont Railway Company (Champlain Flyer), Connecticut Department of Transportation, Port Authority Trans-Hudson Corporation (PATH), Northern Indiana Commuter Transportation District, Maryland Mass Transit Administration (MARC), Virginia Railway Express, Florida's Tri-County Commuter Rail Authority (Tri-Rail), Dallas Area Rapid Transit (DART - Trinity Rail), San Diego Northern Railway (Coaster), Peninsula Corridor Joint Powers Board (Caltrain), Altamont Commuter Express in California, and Central Puget Sound Regional Transit Authority (Sounder). Public authorities own all the commuter railroads. Some of these commuter railroads operate on their own tracks and provide operating rights to freight railroads and Amtrak; others are tenants on trackage owned by freight railroads or Amtrak; and some have both arrangements. Amtrak is the contract operator of services for several of these commuter railroads, while other commuter railroads contract with freight railroads or private companies to operate their services. Long Island Railroad operates it own trains.

1.2 Trends in Railroad Operations

Just as the structure of the railroad industry has changed, so too has the nature of railroad operations. In the years immediately following economic deregulation in 1981, the railroads sought to make more efficient use of their assets. They found themselves with excess physical plant and equipment resources and have worked over the following decade to downsize their operations to improve their profitability.

A number of converging circumstances brought the downsizing activities to an end in the mid-1990's. The U. S. economy continued to grow during the longest peacetime expansion in history, trucking companies faced driver shortages, and highway congestion imposed higher costs on trucking companies.

The freight railroad companies have responded to the growing demand for their services by running more trains, heavier trains, and faster trains with fewer, larger locomotives. The railroad industry's share of the ton-miles of the intercity freight market has grown from less than 38 percent in 1990 to more than 40 percent today. For the first time since World War II, some railroads have capacity constraints on certain lines. The rail lines in the Chicago terminal area in particular have become quite congested. The passage of the North American Free Trade Act (NAFTA) has meant a significant increase in rail traffic across U.S. borders with Canada and Mexico, particularly with intermodal service, both piggyback and containers. Trucking companies, long viewed as competitors of railroads, are now among the railroads' largest customers, contracting with railroads for the long-haul transport of containers and trailers. New and innovative types of intermodal equipment, such as RoadRailers, and roll-on roll-off train sets for hauling trailers, are supplementing traditional piggyback and double-stack container trains (see Figures 1.1 and 1.2). The trucking companies and their shippers are placing greater demands on railroads for speed and delivery reliability of these intermodal shipments. Finally, E-commerce, conducted over the Internet, is changing the way railroads deal with their customers, their suppliers, and one another..

Just as the freight railroad industry is rapidly evolving, so are passenger operators. Amtrak has invested in electrification and new, electrified Acela Express train sets, that provide 150 mile per hour service on portions of the Northeast Corridor between Washington and Boston (see Figure 1.3). Thirty-four States, including New York, Virginia, North Carolina, Ohio, Michigan, Illinois, Wisconsin, Washington, Oregon, and California, are participating in the development of high-speed rail.

Figure 1.1

Road Railers

Figure 1.2

Roll-on roll-off intermodal ramp car

Figure 1.3

Acela Express in service on the Northeast Corridor

In September 1997, the FRA published its report, *High-Speed Ground Transportation for America,* which examined the commercial feasibility of upgraded passenger train service, new high-speed rail service, and maglev service on eight corridors around the country. The report examined whether any of these services would exhibit "partnership potential," meaning: (1) private enterprise must be able to run the corridor—once built and paid for—as a completely self-sustaining entity, and (2) the total benefits of a corridor service must equal or exceed its total costs. The report found that upgraded passenger train service would meet this test of commercial feasibility on all eight corridors examined, that new high-speed rail service could meet it on five of the corridors, and that maglev service could meet it on four.

The most rapidly growing segment of the railroad industry (and of the transit industry) is the commuter rail market. The number of commuter rail trips has grown 27 percent over the past decade. Congestion on highways in and between some major urban areas has brought about renewed interest in commuter and intercity rail passenger services. Commuter ridership has burgeoned in the east, Midwest, and Far West. New commuter rail service is being planned in cities as varied as Burlington (Vermont), Atlanta, Kansas City, and Anchorage. Many of the new services will share rights-of-way and track with freight rail operators. Additionally, as States are looking into new high-speed corridor services to reduce pressures on highways and airports, there is a greater commingling of freight and passenger trains. Both trends bring with them a greater concern about the safety of these services sharing common tracks, as well as implications for scarce capacity.

The restructuring of the freight railroad industry is already producing major shifts in traffic flows. Individual companies now have more than one line between some major urban areas, which may enable freight and passenger traffic to be isolated on separate routes in certain corridors. On other corridors, however, the traffic shifts are resulting in greater congestion, leaving less space for intercity passenger and commuter trains.

1.3 Railroad Safety Trends

Over the past twenty years, the railroad industry has invested over $80 billion in track and equipment. This investment has played a key role in the industry's drastically improved safety record. Since 1981, the frequency of accidents/incidents is down almost 74 percent and the number of accidents per train-mile is down almost 65 percent. In addition to increased infrastructure investment, the improvement is attributed to a number of factors, including application of the results of FRA's and the railroad industry's R&D programs, and improved safety awareness on the part of railroad employees and management.

Of the total number of reportable railroad accidents in 2000, 38 percent were attributed to human factors causes, 36 percent to track defects, 12.5 percent to equipment failures, 2.3 percent to signals, and 12 percent to "miscellaneous" as in Table 1.3.1. These percentages have varied only narrowly within each accident cause category over the past eight years. The total number of casualties decreased from 20,400 in 1993 to 12,580 in 2000. During the same period, fatalities declined from 1,279 to 937 and the number of injuries fell from 19,121 to 11,643. The majority of human factors-caused and track-caused accidents were in yards. The majority of equipment-caused, grade crossing, and "miscellaneous" accidents were on main line track.

FRA believes that there are still too many railroad accidents of all types. With a goal of significantly reducing accidents and casualties, research activities will continue focusing on addressing safety issues in each and every technical area that can reduce the probability of accidents.

Table 1.3.1

Causes of Train Accidents, 1993-2000

	1993	1994	1995	1996	1997	1998	1999	2000
Track	963	911	856	905	879	900	995	1,035
Human factors	865	911	944	783	855	971	1,035	1,147
Equipment	360	293	279	318	271	307	321	372
Signal	54	36	27	49	39	38	49	70
Miscellaneous	369	353	353	388	353	359	372	359
TOTAL	2,611	2,504	2,459	2,443	2,397	2,575	2,772	2,983

Source: FRA Office of Safety

1.4 FRA Institutional Changes

Railroad Safety Advisory Committee (RSAC)

Just as the railroad industry has been undergoing major changes, so has the FRA. Recognizing that a major change in its rulemaking procedures was needed, the FRA in 1996 established the Railroad Safety Advisory Committee (RSAC) to assist with the new process of negotiated rulemakings. RSAC brings together representatives of the large, regional, short line, and commuter railroads as well as unions, States, suppliers, the National Transportation Safety

Board (NTSB), and other groups having an interest in rail safety so that agreement on new regulations can be reached in a fair and equitable manner. The various RSAC working groups have been identifying technological areas requiring further research before agreements can be reached regarding regulations. Some of these technological areas have recently included positive train control and locomotive crashworthiness.

Not anticipated at the time of its creation was how successful the RSAC process would become and the momentum it would develop. Also not anticipated was the substantial amount of time from the management and staff of FRA's R&D program that would be required to support RSAC. However, R&D participation in RSAC ensures that R&D is responsive to the needs of the Office of Safety and that research results in areas covered by RSAC are applied in a timely fashion.

Safety Assurance and Compliance Program (SACP)

In order to improve its relations with the railroad industry, FRA established the Safety Assurance and Compliance Program (SACP), which brings a systems-analysis approach to safety oversight. It provides a vehicle for FRA to address safety issues outside the realm of regulation and reduces the adversarial relationship that often exists between the regulator and the regulated community.

Through SACP, railroad labor and management have engaged in collaborative partnerships with FRA to help identify and solve problems related to rail safety.

Because SACP examinations look for root causes of systemic railroad problems, they can have far reaching affects on railroad safety. For example, a site-specific inspection of a railroad signal malfunction may result in a repair order for that specific signal. A SACP multi-discipline inspection of the same situation may uncover a systemic problem that could lead to repair orders for several hundred railroad signals. This leads to a more efficient handling of safety problems.

Since its inception, SACP has evolved. When SACP was first initiated, FRA envisioned only one type of SACP examination: the audit model. In actual operation, SACP has adapted to a variety of different environments and management cultures. Over time, FRA has identified many positive aspects of the program—what works well and what needs improvement. For example, the identification and correction of the root causes that involved employee-fatigue management (a major safety concern) and internal-process changes on the largest railroads did not lend themselves to an audit-type project.

This experience resulted in gradual shifts and changes in the application of SACP. The cumulative effect was to significantly add to the depth of SACP and to the adoption of "best practices approach" to solving problems—options for correcting safety issues and program processes. The experience also helped to identify areas where changes were needed to improve the overall effectiveness of SACP.

While FRA continues to use the original "audit model" process for small railroads or specific facilities, a different kind of SACP review—the ongoing partnership—has become the norm for the larger railroads. Both types of reviews continue to provide significant input to FRA's safety R&D program.

FRA/FTA Joint Policy Statements

In the late 1990s, FRA began receiving requests from communities for the use of mainline railroad rights-of-way for light rail commuter train operations. Because the jurisdiction of light rail operations falls to the Federal Transit Administration (FTA), while intercity freight and passenger operations falls to FRA, some joint agency accommodation is required as light rail operators seek permission to use main line railroad tracks. The most important safety issues related to shared use include: (1) the potential for a catastrophic collision between light rail and conventional railroad freight and passenger equipment; (2) shared use of highway-rail grade crossings; (3) shared infrastructure; and (4) employee safety. The FRA/FTA joint policy statements, published July 10, 2000, discuss how the two agencies will apply safety laws in different shared use scenarios. FRA will assert jurisdiction over all light rail operations on trackage shared with conventional railroads, including compliance with its highway-rail grade crossing rules. However, FRA and FTA will coordinate oversight where there are concerns about sufficient intrusion detection between parallel operations, and where there are concerns with safety at highway-rail grade crossings, if that is the only connection between the two operators. FRA and FTA have also agreed to cooperate in the management of an R&D program to develop crashworthy commuter rail vehicles, described in Section 4.9 of this Plan.

1.5 Trends in Railroad Research

The FRA manages the program elements described in this Five-Year Plan for RD&D with a small staff of Program Managers. The actual work is carried out elsewhere. Some is carried out at the Transportation Technology Center (TTC) near Pueblo, Colorado. The TTC facility is owned by FRA on land leased from the State of Colorado, and it is operated under a Care, Custody, and Control contract by Transportation Technology Center, Inc. (TTCI), a wholly-owned subsidiary of the AAR. A portion of FRA's RD&D program (see Chapters 4 and 5) is carried out there under contract with TTCI, and another portion is carried out there under a joint funding agreement with the AAR.

Another significant portion of FRA's RD&D program is carried out by or under the supervision of staff of the John A. Volpe National Transportation Systems Center ("Volpe Center"), a unit of USDOT's Research and Special Programs Administration (RSPA) located in Cambridge, Massachusetts. Yet another major portion of FRA's RD&D program is carried out by technical companies working under competitively awarded task-order contracts. The remainder of the R&D program is carried out by universities, railroads, and railroad suppliers, consulting engineers, government agencies and other organizations with appropriate technical expertise through grants, cooperative agreements, interagency agreements and contracts.

The Next Generation High-Speed Rail Technology Demonstration Program enters into cooperative agreements with manufacturers and with States to execute the various demonstration projects. They are described in Chapter 5. The cooperative approach is particularly encouraged because it leverages outside resources, thus minimizing the FRA funding requirements. It also reduces the need for demonstration or deployment funding since partners in the development effort may often also be the end product users; and it affords the FRA a better understanding of the safety needs of the railroad industry as new concepts and technologies are put into use in the railroad environment.

The cooperative approach has proven to be an effective process whereby the FRA, railroads, researchers, States, and private institutions generate the concepts, and with seed funding from the FRA, show the feasibility of an idea or approach. This in turn convinces the industry and contributors of the viability of the idea or approach, thus further securing external RD&D support from the participants.

The FRA's RD&D activities include reviews of technical literature to identify technological opportunities applicable to railroad safety and high-speed passenger operations. This effort consists of the scanning of technical and scientific literature in all fields of transportation and other engineering fields that might have applicability to railroad issues. The goal is also to identify and establish public-public and public-private partnerships for research, development, and demonstration activities. In an era of constrained resources, it is important that research findings and technological developments from all possible sources be brought to bear on improving the safety and operational efficiency of railroads. FRA addresses these issues through an appropriate combination of study, analysis, simulation, laboratory testing, and field-testing.

Despite record traffic levels in the freight railroad industry and the creation of fewer, larger railroad companies, financial difficulties have caused the large railroads to cut back significantly on their in-house R&D programs and to reduce their jointly funded program carried out through TTCI. Furthermore, Amtrak and the commuter railroads have no surplus funds to spend on R&D. These situations underscore the importance of the FRA RD&D program.

The FRA, in an effort to ensure maximum leveraging of RD&D funds and to eliminate duplication, cooperates extensively with the AAR representing the large freight railroads, the American Short Line and Regional Railroad Association (ASLRRA) representing smaller freight railroads, the American Public Transportation Association (APTA) representing the commuter railroads, Amtrak, the Railway Progress Institute (RPI) representing the railroad supply industry, individual suppliers, the FTA, the National Transportation Safety Board (NTSB), and the various States. Cooperation with the AAR occurs primarily at the TTC in the areas of track/train interaction, track safety research, bearing defect detection, braking systems, grade crossings, train control, and hazmat transportation. The ASLRRA is sharing the cost with FRA of a study of heavy axle loads. The RPI arranges for its supplier-members to provide material and equipment for the Facility for Accelerated Service Testing (FAST) track at TTC, and also participates in the hazmat transportation projects. APTA, Amtrak, and FTA cooperate with FRA on projects aimed at improving protection for railroad passengers. States and individual suppliers are providing cost sharing for the major projects being carried out under the Next Generation High-Speed Rail Technology Demonstration Program. FRA carries out cooperative activities with foreign entities as well, jointly sponsoring tank car and grade crossing research activities with Transport Canada and wheel-rail interaction work with the National Research Council of Canada, and sharing research results with the European Railway Research Institute.

FRA representatives serve on the AAR's Railway Technology Working Committee and on a number of other committees involved in engineering, mechanical, and signaling and communications issues. FRA staff also actively participate in committees of the Transportation Research Board (TRB) and the American Railway Engineering and Maintenance of Way Association (AREMA). Such participation ensures that duplication of effort is avoided.

Appendix B contains descriptions of FRA's University Research Grants Program, USDOT's Small Business Innovative Research (SBIR) Program, and the Ideas Deserving Exploratory Analysis (IDEA) Program administered by the TRB for FRA and other USDOT modal administrations.

It is difficult to identify specific goals and outcomes for the FRA RD&D program in a five-year timeframe. Only some of the projects will be completed within five years, and not all will produce results that can or should be implemented. The rate at which project results are implemented depends in part on the benefit-cost ratios of the technologies or processes developed in the individual projects. Also, the rate depends in part on the availability of and competition for capital in the railroad industry, and in part on the rate at which FRA mandates their implementation. The recent improvements in railroad safety are the result of R&D conducted in the 1970's and 1980's along with the sizeable investments railroads made in infrastructure and rolling stock during the 1980's and 1990's. At best, implementation of the results of only a small portion of the projects described herein will have begun five years from now. Effects of the projects described in this plan will begin to show up in railroad safety and efficiency statistics in earnest about ten years from now. This plan describes an RD&D program that will have long-term effects on the U.S. railroad system.

1.6 Peer Review

The National Academy of Science and the National Academy of Engineering report, entitled *Evaluating Federal Research Programs*, recommended that Federal agencies use peer reviews as part of the process of establishing the direction and content of their R&D programs. At the request of the Senate and House Appropriations Committees, and in accordance with the recommendations of National Academies, FRA contracted with the TRB for the establishment of a committee, initially called the Committee for an Assessment of Federal High-Speed Ground Transportation R&D, and, subsequently, the Committee for Review of the FRA R&D Program. This committee, which is made up of representatives of States, railroads, labor unions, universities, financial institutions, and research organizations, has been meeting twice annually. It was asked to address the following aspects of FRA's R&D activities:

- The management structures and approach.
- The current direction and allocation of funds to the various program areas.
- The balance of Federal, State, and private-sector input and cost sharing.
- Directions and objectives in the Five-Year Plan for RD&D.

One of the major recommendations of the Committee was that FRA develop a structured process to identify safety research areas and select specific safety R&D projects for funding. FRA took that recommendation to heart and, working with the Volpe Center, developed the process that is described in detail in Chapter 3 and applied it to structuring the safety R&D program.

Appendix C contains the most recent letter report from the Committee summarizing its work over the past three years and providing both its recommendations and the FRA responses to them.

1.7 R&D Management Self-Assessments

In 1998, the Secretary of Transportation directed all departmental R&D facilities to undertake quality assessments. FRA ensured that the management of TTCI would undertake quality assessments in connection with their new ten-year contract for the operation of the TTC. In 1999, the Secretary directed all R&D organizations to undertake quality assessments, standardizing on the seven Baldrige Award criteria: leadership, strategic planning, customer and market focus, information and analysis, human resources focus, process management, and business results.

FRA's Office of R&D conducted its self-assessment in July 2000. It graded itself relatively high in the categories of organizational leadership, strategy development and deployment, customer and market knowledge, work systems, employee well being and satisfaction, and supplier and partnership processes. Categories calling for improvements were customer satisfaction and relationships, measurements of organization performance, employee education, product and service processes, and support processes.

FRA's Office of R&D will continue to use the Baldrige Award criteria for self-assessment as an integral part of its planning process. The Baldrige Award criteria have been developed primarily for large private sector non-R&D organizations. Consequently, the Office of R&D, a small public sector R&D organization, must apply the criteria in their spirit, not literally. Nevertheless, the Baldrige Award criteria really represent structured common sense, and therefore they are appropriate for helping the Office of R&D identify its strengths and weaknesses.

1.8 Five-Year Plan

The following chapters in this Five-Year Plan for RD&D describe how it was developed and what FRA hopes to accomplish with its Research, Development, and Demonstration activities over the next five years.[1]

Chapter 2 describes the components that make up Intelligent Railroad Systems, a related set of technologies that are expected to make railroad operations safer, more secure, and more efficient over the coming decade.

Chapter 3 describes a structured process using safety statistics that was adopted by FRA to identify safety research areas and select specific safety R&D projects for funding.

Chapter 4 describes the five-year plan for the ten program elements that comprise FRA's R&D program: railroad system issues—safety, security, and environment; human factors; rolling stock and components; track and structures; track-train interaction; train control; grade crossings; hazardous materials transportation; train occupant protection; and R&D facilities and equipment.

Chapter 5 describes the five-year plan for the four program elements that comprise FRA's Next Generation High-Speed Rail Technology Demonstration Program: positive train control, non-electric locomotive, high-speed grade crossing protection, and track and structures.

Chapter 6 describes the five-year plan for FRA's Magnetic Levitation Technology Deployment Program.

Chapter 7 describes FRA's plans for undertaking Strategic Workforce Planning activities and establishing Professional Capacity Building capabilities.

Chapter 8 presents the enacted budgets for FY2001 and FY2002, and the requested budget for FY 2003.

Chapter 9 summarizes all the prior chapters and describes how FRA anticipates updating this Five-Year Plan for RD&D.

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[1] Neither the sequence of the chapters, nor the sequence of the program elements within Chapters 4, 5, and 6, represents a prioritization of RD&D activities by the FRA.

FRA RD&D:
Fifteen Powers of Ten

Charles and Ray Eames produced a remarkable film for IBM to show at its exhibit at the 1964 New York World's Fair. Called *The Powers of Ten*, it was all about the relative size of things in the universe and the effect of adding another zero. Forty-two powers of ten span human-kind's firm knowledge, ranging from quarks residing within atoms to the universe containing billions of galaxies.1

Six orders of magnitude, from a kilometer to a millimeter, cover the domain of familiarity for human beings. Most scientific research over the span of human existence has taken place at such a scale. As time has progressed, however, research has pushed at these dimensions, gaining an understanding of what takes place in both larger and smaller domains.

The Federal Railroad Administration's research interests cover fifteen powers of ten, from 10^{-6} meters where we are concerned about microelectromechanical systems and low- friction surface roughness, up to 10^{9} meters where we are concerned with the network flow effects on the national railroad network and the amount of fiber optic cable installed on railroad rights-of way.

The film, *The Powers of Ten*, is structured about a "voyage" that starts with picnickers at Grant Park in Chicago and moves out to the edges of the universe and in to innermost parts of atoms in the cells of the picnicker's skin.

Following is a "voyage" through the domains with which railroaders and FRA staff members are concerned. Items with size of a similar order of magnitude are listed together between the various "powers of ten" meters.

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[1] For further information, see *Powers of Ten* by Philip and Phylis Morrison and the Office of Charles and Ray Eames. New York: Scientific American Library, c1982.

10^{-6} meter (1 micron or 1,000 nanometers)

- microelectromechanical systems
- low-friction surface roughness

10^{-5} meter (10 microns)

- crystalline structure of rail and wheel steel
- crystalline structure of tank car weld
- bearing surface roughness

10^{-4} meter (100 microns)

- rail flaw
- injector nozzle orifice

10^{-3} meter (1 millimeter)

- integrated circuit for microprocessor

10^{-2} meter (1 centimeter)

- contact area between wheel and rail
- ballast particle
- sensor injector nozzle

10^{-1} meter (10 centimeters)

- rail spike
- brake valve
- tie pad and plate
- locomotive radio antenna
- GPS/NDGPS antenna
- hot bearing detector
- locomotive cab display
- mobile radio
- signal relay
- AEI tag
- brake shoe
- coupler knuckle
- hand brake wheel

10^{0} meter (1 meter)

- rail joint bar
- draft gear
- wheel
- cross tie
- brake beam
- AEI reader antenna
- pantograph
- dispatcher work station
- railroad worker
- hi-rail vehicle
- signal mast
- track misalignment

10^{1} meters (10 meters)

- container
- ballast tamper
- rail car
- locomotive
- catenary pole
- turnout
- base radio antenna mast
- culvert
- small bridge
- NDGPS antenna

10^{2} meters (100 meters)

- spiral on a high-speed curve
- medium-sized bridge
- articulated intermodal car
- passenger train
- continuous welded rail string

10^{3} meters (1 kilometer)

- tunnel
- freight train
- major bridge
- rail yard

10^{4} meters (10 kilometers)

- long tunnel
- long trestle
- industrial and switching railroad
- maglev demonstration project

10^{5} meters (100 kilometers)

- commuter railroad
- shortline railroad
- high-speed passenger railroad

10^{6} meters (1,000 kilometers)

- regional railroad

10^{7} meters (10,000 kilometers)

- GPS satellite orbit altitude
- large railroad

10^{8} meters (100,000 kilometers)

- U.S. railroad network
- fiber optic cable on railroad rights-of-way

10^{9} meters (1,000,000 kilometers)

chapter 2.0

A Vision for the Future: Intelligent Railroad Systems

A theme cutting across virtually all the RD&D program elements is the use of sensors, computers, and digital communications to collect, process, and disseminate information to improve the safety, security, and operational effectiveness of railroads. Intelligent Transportation Systems (ITS) for highways and mass transit are based on these technologies, as are the new air traffic control and maritime vessel tracking systems. Military services, major parcel delivery companies, pipeline operators, and police, fire, and ambulance services also use these technologies. The Federal Railroad Administration and the railroad industry are working on the development of **Intelligent Railroad Systems** that would incorporate the new sensor, computer, and digital communications technologies into train control, braking systems, grade crossings, and defect detection, and into planning and scheduling systems as well.

The new Intelligent Railroad Systems are key to making railroad operations—freight, intercity passenger, and commuter—safer and more secure, reducing delays, reducing costs, raising effective capacity, improving customer satisfaction, improving energy utilization, reducing emissions, and becoming more economically viable. The systems can be implemented as independent systems, in which case their benefits will be limited, or they can be implemented as integrated systems, in which case the benefits will be compounded. FRA, through its Research, Development and Demonstration program elements, is encouraging the railroad industry to adopt the integrated approach when implementing these systems.

Following are descriptions of the components of Intelligent Railroad Systems. Work on certain of the components for which Federal support is deemed appropriate will be carried out in the program elements described in Chapters 4 and 5 of this Five-Year Plan for RD&D.

Digital data link communications networks provide the means for moving information to and from trains, maintenance-of-way equipment, switches and wayside detectors, control centers, yards, intermodal terminals, passenger stations, maintenance facilities, operating data systems, and customers. Data link communications will replace or supplement many of today's routine voice communications with non-voice digital messages and will effectively increase the capacity of available communications circuits and frequencies. Data link communications will utilize radio frequencies to communicate to and from mobile assets, and between locomotives in a train consist, and can use a variety of transmission media (owned either by railroads or commercial telecommunications carriers) to communicate between fixed facilities. These media include microwave radio, fiber optic cable, buried copper cable, cellular telephones, communications satellites, and even traditional pole lines. With data link communications, the information is digitally coded and messages can be discretely addressed to individual or multiple recipients.

The U.S. Government, through the Federal Communications Commission, has assigned to the railroad industry 182 frequencies in the VHF band (160 MHz) and 6 pairs of frequencies in the UHF band (900 MHz). The UHF frequencies are being used for digital communications; and some railroads have converted some of their assigned VHF frequencies from analog to digital communications. The conversion is expected to accelerate during the coming decade.

Nationwide Differential GPS (NDGPS) is an augmentation of the Global Positioning System (GPS) that provides 1- to 3-meter positioning accuracy to receivers capable of receiving the differential correction signal[1]. It is an expansion of the U.S. Coast Guard's Maritime DGPS network and makes use of decommissioned U.S. Air Force Ground Wave Emergency Network (GWEN) sites to calculate and broadcast the differential correction signals. NDGPS receivers will be placed on locomotives and maintenance-of-way vehicles where they will calculate location and speed, and that information will be transmitted back to the railroad control center over the railroad's digital data link communications network. NDGPS is now operational with single-station coverage over about 80 percent of the landmass of the continental U.S., and is expected to be fully operational with dual-station coverage throughout the continental U.S. by the end of 2004. To ensure continuity, accuracy, reliability, and integrity, NDGPS is managed and monitored 24 hours a day, 7 days a week from the Coast Guard's Navigation Center in Alexandria, Virginia. NDGPS provides a GPS integrity monitoring capability; it gives an alarm to users within 5 seconds of detecting a fault with the signal from any GPS satellite. NDGPS signals are available to any user who acquires the proper receiver, without fee.

Positive Train Control (PTC) systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. PTC systems will improve railroad safety by significantly reducing the probability of collisions between trains, casualties to roadway workers and damage to their equipment, and over speed accidents. The National Transportation Safety Board (NTSB) has named PTC as one of its "most-wanted" initiatives for national transportation safety. PTC systems are comprised of digital data link communications networks, continuous and accurate positioning systems such as NDGPS, on-board computers with digitized maps on locomotives and maintenance-of-way equipment, in-cab displays, throttle-brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control center computers and displays. PTC systems may also interface with tactical and strategic traffic planners, work order reporting systems, and locomotive health reporting systems. PTC systems issue movement authorities to train and maintenance-of-way crews, track the location of the trains and maintenance-of-way vehicles, have the ability to automatically enforce movement authorities, and continually update operating data systems with information on the location of trains, locomotives, cars, and crews. The remote intervention capability of PTC will permit the control center to stop a train should the locomotive crew be incapacitated. In addition to providing a greater level of safety and security, PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and greater track capacity. They will assist railroads in measuring and managing costs and in improving energy efficiency. Pilot versions of PTC were successfully tested a decade ago, but the systems were never deployed on a wide scale. Other demonstration projects are currently in the planning and testing stages. Deployment of PTC on railroads is expected to begin in earnest later this decade.

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[1] According the 1999 Federal Radionavigation Plan, "The predictable accuracy of the NDGPS Service within all established coverage areas is better than 10 meters (2drms). NDGPS accuracy at each broadcast site is carefully controlled and is typically better that 1 meter." Even though those are the published figures, field data suggests even better performance. High-end receivers have been able to maintain a better than 1 meter accuracy even at the edge of the coverage area.

E**lectronically controlled pneumatic (ECP) brake**s - Current train braking systems use air to both power the brakes and to initiate brake applications and releases. New ECP brakes use an electronic signal to initiate brake applications and releases, and thereby permit the simultaneous application of all brakes on a train, substantially shortening the braking distance and reducing in-train coupler forces and slack action. One system under test uses a wire line to convey the electronic signals; another uses spread spectrum radio frequencies to convey the signals. Either type of system also enables data to be collected from on-board equipment, track, and commodity sensors, and moved to the locomotive where it can be observed by the crew and transmitted over the digital data link communications network to control centers, maintenance facilities, and customers, as appropriate. ECP brakes have been tested on unit coal trains and on double-stack intermodal container trains in the U.S., Canada, and Australia, and have been shown to improve train energy efficiency. More widespread deployment is expected in the coming decade.

Knowledge Display Interfaces - In-cab PTC displays will provide status information and command and control instructions to the locomotive crews. They will display train position and speed as calculated by the positioning system, the upcoming route profile, in-train forces, actual and recommended throttle and brake settings, speed control instructions and authorities as received over the data link from the control centers, on-board locomotive health information from all units in the consist, and data from on-board and wayside equipment, track, and commodity sensors. They will also display the train consist and special handling instructions for cars from work order reporting systems, data from the end-of-train device and ECP brakes, and any other information that can be sent over the data link. Control center displays for dispatchers will show the precise location and speed of each train and maintenance-of-way vehicle, train consists, performance against schedule, and the plans generated by the tactical and strategic traffic planners. The challenge in developing the displays is to ensure that only necessary information, and no unnecessary information, is displayed. Displays currently being installed on locomotives and at control centers will have the capability to display the information that will be generated by the Intelligent Railroad Systems.

Crew registration and time-keeping systems will use identification techniques such as passwords, electronic card keys, or biometrics to insure that only authorized train crewmembers are permitted to control a locomotive. The control center would issue a movement authority only when it has confirmation that the designated crew is on board and logged in. The times that crew members log on duty on the locomotive, depart their initial terminal, arrive at their final terminal, and log off duty, can be automatically sent over the digital data link communications network to the control center and to the operating data system. This would eliminate manual record-keeping and data entry chores and ensure that accurate times are entered in the operating data system for payroll purposes.

Crew alertness monitoring systems promote on-duty alertness and vigilance of train crews through the use of non-invasive technology applications. Mental lapses and other human errors that result in unsafe safe job performance are often due to reduced alertness or vigilance. Real time monitoring and feedback of individual alertness levels will allow crew members to modify their behavior and reduce their risk of unsafe performance. Risk-appropriate countermeasures, such as napping, social interaction, and postural changes, will be suggested by the system, and in the case of high risk (e.g., the crewmember falls asleep), the system can both notify the control center over the digital data link communications network and stop the train. Real time monitoring and feedback of population alertness levels will allow managers to dynamically adjust work schedules and help ensure the most well-rested individuals, or teams, are available for high-risk assignments. Models of fatigue and alertness in the system will accurately predict future risk of non-alertness in individuals and groups of individuals so that countermeasures can be applied to maintain optimal performance either before or throughout a work shift.

Track forces terminals (TFTs) provide the means for moving information and instructions to and from roadway workers. A TFT consists of a laptop computer or personal digital assistant (PDA), data radio, and positioning system receiver. The TFT sends position reports from the field to the control center over the digital data link communications network, and it displays authorities received from the control center to the roadway workers. With a TFT, roadway workers can obtain authorities without talking to a dispatcher. The TFT can display the location of all trains in the vicinity, and the crew can determine when the track will be unoccupied and use the TFT to request track occupancy for that time. The control center computer checks the proposed authority for safety, and if it is safe, the dispatcher grants the authority which then appears automatically on the dispatcher's display and on the TFT. At the completion of track work, the TFT can be used to place a slow order on the track by transmitting the information to the control center computer. The TFT can also be used to transmit administrative data (e.g., gang time, machine usage and status, material usage and requirements, and production reporting information) to track maintenance facilities and the railroad operating data system.

Automatic Equipment Identification (AEI) tags have been installed on both sides of all freight cars and locomotives in the U.S. and Canada since 1995. AEI readers, installed along the track at yards, terminals, and junctions, interrogate the tags over UHF radio frequency (900 MHz), and the tags respond with the unique initials and numbers identifying each car. The readers assemble the information from all cars on a train and then transmit the entire train consist to the railroad's operating data system over the digital data link communications network or over dedicated telephone lines. Because PTC systems know at all times the precise location of every train, AEI, when combined with PTC, permits railroads to know at all times the precise location of every car and shipment. Some railroads have installed substantial numbers of readers and have integrated them with their operating data systems; others have not. Installation and integration of the full network of readers is expected in the first half of this decade. AEI readers can be integrated with wayside equipment sensors to provide positive identification of vehicles with defects.

Wayside equipment sensors are installed along the track to identify a number of defects that can occur on rolling stock components and to transmit information about the defects so that trains can be stopped if necessary and maintenance crews can perform repairs as required. Among the defects that can be detected by the wayside sensors are overheated bearings and wheels, deteriorating bearings, built-up wheel treads, worn wheels, cracked wheels, flat wheels, derailed wheels, excessive truck hunting, dragging equipment, excessive lateral and vertical loads, skewed trucks, and excessively high and wide loads. AEI readers integrated with the sensors will provide positive identification of vehicles with defects. Information from the sensors is now usually transmitted by voice-synthesized radio. Once data link communications networks are installed, the information will be transmitted from wayside interface units at the sensors to train crews, control centers, and maintenance facilities.

Wayside track sensors are installed to identify a number of defects that can occur on and alongside the track. They can also identify conditions and obstructions along the track, and to transmit the information so that the train can be stopped or slowed if necessary allowing maintenance crews to perform repairs as required. Among the conditions and defects that can or will be detected by wayside sensors are switch position, broken rail, misaligned track, high water, rock and snow slides, excessive rail stress, misaligned bridges and trestles, blocked culverts, weather information (temperature, rate of change of temperature, wind velocity, precipitation, etc.), earthquakes, and general security and integrity information regarding track and structures. Information from these sensors is now usually transmitted by wayside signal indication. Once data link communications networks are installed, the information can be transmitted from wayside interface units at the sensors to train crews, control centers, and maintenance facilities.

Locomotive health monitoring systems consist of sensors mounted on engines, traction motors, electrical systems, air systems, exhaust systems, and fuel tanks on locomotives. Most new locomotives are equipped with most of these sensors. The data from all units in the consist will be displayed to locomotive crews, and are collected in on-board computers for retrieval when locomotives arrive at maintenance facilities. The data will be transmitted over the digital data link communications network to control centers, maintenance facilities, and motive power distribution centers to permit real-time monitoring of locomotive performance and efficiency. Each of those places could make an inquiry over the data link to a locomotive to receive a health status report. The data will also be collected at maintenance facilities and analyzed to permit maintenance to be done on an as-needed rather than scheduled basis. Traction motor performance in both traction and dynamic braking modes will be monitored. Locomotive health monitoring systems will improve locomotive energy efficiency and emissions. Limited testing of real-time locomotive health monitoring has taken place over the last decade.

Energy management systems (EMSs) are separate computer programs installed on locomotives to optimize fuel consumption and/or emissions. An EMS would receive information on track profile and conditions, speed limits, the train and locomotive consist, locomotive engine fuel performance characteristics, information from the locomotive health monitoring systems on engine and traction motor performance, train length and weight, and target times at specific locations as determined by the tactical traffic planner. It would then determine a recommended train speed that met service requirements, while minimizing fuel consumption and/or emissions and providing good train-handling characteristics. Conceptual work has been done on EMSs, but a prototype system has not yet been implemented.

Vehicle-borne track monitoring sensors will be installed on inspection cars, and perhaps eventually on locomotives, to identify a number of defects and conditions that occur on and alongside the track so that trains could be stopped or slowed if necessary and maintenance crews could perform repairs as required. Among the defects that could be detected by the on-board sensors are rail flaws, broken rail, misaligned track, and excessive rail stress. Weather information (temperature, rate of change of temperature, precipitation, etc.) could also be collected. Information from all these sensors could be displayed in the inspection car or locomotive cab and would be transmitted from the car or locomotive via the digital data link communications network to control centers and maintenance crews.

Car on-board component sensors will be installed on rolling stock to identify a number of defects and to provide information so that the train can be stopped if necessary and maintenance crews can perform repairs as required. Among the defects and conditions that can be detected by the on-board sensors are overheated bearings and wheels, impacts and vibrations from flat or derailed wheels or corrugated track, excessive truck hunting, excessive longitudinal forces, and braking system status. Information from the sensors is transmitted over the ECP brake system's communications channel to the locomotive where it can be observed by the crew and transmitted over the digital data link communications network to control centers and maintenance facilities. Some development of these sensors has occurred, but deployment of the digital data link communications network and ECP brakes is a prerequisite for the installation of such sensors.

Car on-board commodity sensors are being installed on freight cars to monitor the status of the commodities being carried. Among the parameters that can be measured by the on-board sensors are temperatures, pressures, load position, radiation, and vibrations. The security of shipments can also be monitored. Information from the sensors will be transmitted over the ECP brake system's communications channel to the locomotive where it can be observed by the train crew and transmitted over the digital data link communications network to control centers, maintenance facilities, and customers. If problems are detected, the train can be stopped and maintenance crews can perform repairs. Some customers are using proprietary sensor and satellite communications packages to obtain the data directly from the cars, bypassing railroad information channels.

Intelligent grade crossings - Intelligent Transportation Systems (ITS) for roadways come together with Intelligent Railroad Systems at Highway-Rail Intersections (HRIs). Information about train presence and arrival times, generated either by a PTC system or track circuits, or off-track sensors, will be provided to highway traffic control centers via the digital data link communications network, and to motor vehicle operators via roadside traffic information signs or via dedicated short-range radios to in-vehicle displays or audio warning systems. Similarly, sensors at HRIs will send information to railroad control centers and trains over the digital data link communications network should an HRI be blocked by a stalled vehicle. Demonstrations of intelligent grade crossing devices have been conducted in eight states. An architecture for HRIs was developed as part of the ITS National Architecture, and work on the development of standards for intelligent grade crossings has begun to insure that there will be national interoperability.

Intelligent weather systems consist of networks of local weather sensors and instrumentation—both wayside and on-board locomotives— combined with national, regional, and local forecast data to alert train control centers, train crews, and maintenance crews of actual or potential hazardous weather conditions. Intelligent weather systems will provide advance warning of weather-caused hazards such as flooding, track washouts, snow, mud, or rock slides, high winds, fog, high track-buckling risk, or other conditions which require adjustment to train operations or action by maintenance personnel. Weather data collected on the railroad could also be forwarded to weather forecasting centers to augment their other data sources. The installation of the digital data link communications network is a prerequisite for this activity.

Tactical traffic planners (TTPs) produce plans showing when trains should arrive at each point on a dispatcher's territory, where trains should meet and pass, and which trains should take sidings. As the plans are executed, a TTP takes the very detailed train movement information provided by the PTC system and compares it with desired train performance. If there are significant deviations from plan, the TTP will re-plan, adjusting meet and pass locations to recover undesired lateness. TTPs make use of sophisticated non-linear optimization techniques to devise an optimal dispatching plan. Once a TTP prepares a plan, the dispatcher need only accept it. Then the computer-assisted dispatching system of PTC produces all authorities needed to execute the plan and sends them over the digital data link communications network to trains and maintenance-of-way vehicles. Some prototype TTPs have been developed and tested.

Strategic traffic planners (STPs) - TTPs cannot function without knowing the schedule for each train. STPs measure train movements against a set of externally defined schedules that include information on scheduled block swaps and connections, both internal and with other railroads. Integrating a flow of information about actual train performance from the TTP, the performance of connections, and detailed consist information for all trains from operating data systems. STPs make cost-minimizing decisions on whether, and how, train priorities and schedules might be adjusted on a real-time basis. STPs are the highest-level real-time control system in the PTC hierarchy. STPs will be able to display the performance of trains against schedule, the real-time location of every train by type (e.g., coal, intermodal, grain, intercity passenger), and the location of trains at future times based on current performance. The Federal Aviation Administration developed an STP (called "central flow control") to support the U.S. air traffic control system; the same philosophy could apply to railroad STPs.

Yard management systems (YMSs) provide the essential link between the movement of trains and the movement of cars. The YMS will receive real-time information on the location and make up of each train on the system and will keep track of all cars in the yard. It will receive goals and objectives from the STP. This will allow the YMS to determine the best way to make up trains, that is, the order in which arriving cars should be classified, the order in which they should be pulled from the lead tracks, and the order in which outbound trains should be made up. The YMS will account for the time that trains will be arriving, the times they should be departing, and the time required for each yard operation to be performed. It will supply a forecast of yard departure times for each of the trains to the STP so that it will be able to perform better its job of creating time targets for smooth system functioning.

Work order reporting (WOR) systems send instructions over the digital data link communications network from the control center to train crews regarding the setting out and picking up of loaded and empty cars enroute. When crews acknowledge accomplishment of work orders, the system automatically updates the on-board train consist information and transmits information on car location and train consists back over the digital data link communications network to the railroad's operating data system and to customers. WOR information can be displayed in locomotives on the same screens that would display PTC instructions and information. One major railroad has deployed a WOR system using a dedicated digital data link communications network.

Locomotive scheduling systems use data regarding train schedules, physical terrain, locomotive characteristics, locomotive health information, locomotive servicing and maintenance schedules, and expected train consists to assign locomotives to trains, making use of linear programming algorithms. Improved train consist information coming from a car scheduling and reservation system can result in better locomotive allocations. Keeping trains and, therefore, locomotives on schedule is necessary to execute future locomotive assignments. Locomotive scheduling systems have been developed and are in use on most railroads. If the locomotive scheduling systems could be provided with real-time information on locomotive health, on current and future locations of trains, and on expected train consists, the utilization rate of locomotives could be significantly improved.

Car reservation and scheduling systems - Freight car reservation systems allow customers to reserve freight car capacity and routing in advance; freight car scheduling allows railroads to plan the movements of individual freight cars to match up with known customer demand. Scheduling of the movement of cars will reduce cross hauling of empty cars and reduce delays to loads and empties at intermediate yards. This reduces fleet size requirements and improves asset utilization. Car reservation and scheduling systems, which are similar to airline seat reservation and scheduling systems, can only work when railroads operate on a schedule, and, in turn, car reservation and scheduling systems provide information to locomotive scheduling systems and are a prerequisite for yield management. One major railroad developed and used a car scheduling system for a number of years. However, the railroad's inability to keep its trains on schedule meant that cars often had to be reassigned to different trains in the course of their journeys.

Crew scheduling systems - When train operations are scheduled and stay on schedule, crew assignments can also be scheduled a number of days or weeks in advance. That will result in predictable work hours for most crewmembers, and will enable them to schedule regular periods of sleep and recreation, reducing family and social tensions and emotional and physical stress. Crew scheduling systems would use information from the STP and from PTC along with information about crew members (seniorities, current locations, schedule preferences, most recent assignment worked) and Hours of Service Act and labor contract provisions to match up trains and crews most cost-effectively. Some European railroads currently use such long-term crew scheduling systems.

Yield management systems enable railroads to establish variable pricing policies that maximize profit by linking the price charged for a service to customer demand. Applicable to both freight and passenger railroad operations, yield management requires reservation and scheduling capabilities, and sophisticated information systems to keep track of changing capacity, complex service variables, and multiple prices. With yield management, railroads can identify opportunities for filling up existing capacity with lower-priced services for customers who are less service-sensitive. At the same time, it will show when and how much to increase prices for service-sensitive customers shipping or traveling at peak times. Amtrak and all major airlines now use yield management.

Emergency notification systems installed at control centers provide for the automated notification of all involved organizations following railroad accidents, incidents, or threats. They provide for better coordination and control of the involved organizations: railroad response crews; police, fire, and emergency medical services, as well as other appropriate local, state, and national authorities. The systems are tied to geographical interfaces. When reports of accidents, incidents, or threats arrive over the digital data link communications network with precise and accurate geographical coordinates, the emergency notification system can identify the emergency responders for that locale, notify them, and provide them with correct location information. The systems monitor the timing of the call-outs and the arrival or emergency services at the scene so that performance can be analyzed. The systems enable the faster resolution of problems and resumption of rail service.

Travelers Advisory Systems use real-time train location information generated by GPS receivers on locomotives and transmitted over digital data links to provide intercity passenger train and commuter train riders with expected arrival times of their trains. The information can be displayed on dynamic message boards at stations and on map displays posted on the World Wide Web. The information can be used by the passenger railroads, which are often tenants on freight railroads, to automatically collect data on the on-time performance of their trains. These systems are typically implemented as free-standing systems using cellular or satellite communications, but they can be integrated with other systems, using information from the PTC system and transmitting it over the railroad's digital data communications network.

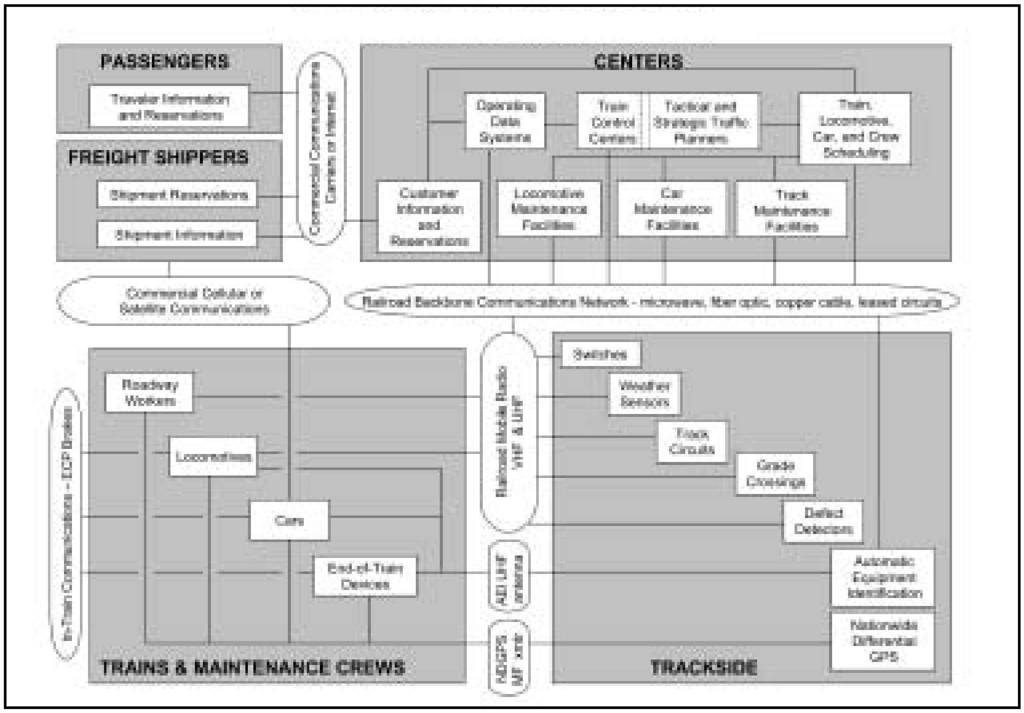
System security is one of the overarching issues that effects deployment of many of the systems and initiatives just described. It must be designed into Intelligent Railroad Systems before they are deployed. Data regarding trains, cars, crews, and shipments must be kept confidential or private, and unwarranted extraction of information from the digital data link communications network must be prevented. Authentication of data will ensure that the content is genuine, unaltered, and complete. Encryption is the security mechanism that converts plain text into cyber text that is unintelligible to those who do not have access to the decryption algorithm. Archiving of data from Intelligent Railroad Systems must also be done in a secure manner through the control of access privileges to prevent loss of data. Intelligent Railroad Systems must also be designed to enable control centers to identify and verify emergencies from the data inputs they receive, and to provide notification of emergencies to appropriate public sector authorities and railroad officials.

The Architecture of Intelligent Railroad Systems

In order to show how all of the previous systems and initiatives fit together, and to help identify the key interfaces for standardization, an architecture for Intelligent Railroad Systems is being developed. A first step in this direction is shown in the following Figure 2.1, which is a top-level interconnect diagram that identifies the key elements of Intelligent Railroad Systems and the communications link interfaces between them. It is based on conventions developed by the Architecture Development Team for the National ITS Architecture. This type of diagram is known as a "sausage diagram" in which the "sausages" represent the various types of communications links that move information between vehicles, fixed installations along the transportation right-of-way, control and management centers, and customers.

Figure 2.1

Intelligent Railroad Systems –Subsystems and Interconnects



2020 Dispatching

What will railroad dispatching be like two decades from now? This sketch offers one possible answer, in the words of a Great Western & Pacific dispatcher showing off his workstation to an authorized visitor.

"Ready. Hancock. Railhawk. Six-seven-four-one. Dispatch Woodbridge. Date six-ten-thirty. Time zero-seven-zero-three. Cover TS one-seven-one and TS one-seven-five. Request display. Over."

"Come on in. Sorry for ignoring you. Have a seat there. I was just saying good morning to the system and setting up my territory. Now that I've signed on I'll show you how things work. Watch over here — the wall will light up in a second. There we go. Rather impressive, huh? Dispatching at the GW&P has come a long way from the days of CTC and PTC.

"The system's in a display mode right now. When I talked to the machine a minute ago, I told it who I was, where I was, the date and time, and what track segments I need. Then I asked for display mode. That means we can look at the trains on the wall displays, but we can't talk to them or get live camera closeups or change their speeds or redo the traffic plan. All that comes in the control mode, which I can't get to right now because Campbell is still on duty. If I had asked for control mode when I signed on, the machine would have scolded me.

"See the window at the top left? The system's asking me for an on-duty acknowledgment — an important detail, since that's how I get paid. I'll ignore it for now, because I can't really be a dispatcher and a tour guide at the same time. There's twenty minutes or so before I need to go on duty — that should be plenty of time to walk you through the basics.

"What you see on the wall are all the default displays for my workstation — the ones I've selected for my user profile. They're the displays I'm most likely to need most of the time. Of course I need other displays at times, but they're easy to get to — I'll show you how that works in a little bit. The map to the left shows the territory I'm responsible for — at least for right now. They can split things up just about any way they want, so when traffic is lighter — like at night — fewer dispatchers can carry the load by each taking a bigger piece.

"This is an overview. It shows the whole territory, but not in great detail. You do see all the trains and vehicles, thanks to the data link and the new GPS III satellites. We're running the trains close together today. We usually do these days, with trucking on the decline and rail traffic way up. It's kind of scary, when you realize the trains are moving at 140 kilometers an hour and some of them are just two or three kilometers apart. No problem, really. The system always knows what's safe and what's not. It has a good pedigree — we haven't had a collision for years now.

"Look closely and you'll see the trains moving along the track. What we see here is what's happening in the field — right now, eight hundred miles away. Look, 7940 east just stopped on the main. The flashing train symbol tells us he's stopped, and you can see the symbol is staying in one place now. The purple bar shows that he's at the edge of maintenance-of-way territory. He's waiting for clearance from the gang foreman there. We'll see a green bar along the track when he gets his authority to go. If that train weren't authorized to stop, we'd get a message and an audible alarm. As it is, we'd get the alarm if the train didn't stop — and so would he. Onboard enforcement would put the brakes on. Train movements are pretty closely controlled these days.

"The next screen over is a control view of Falls City to Jones Junction. Since the territory is more blown up, the train movements are more obvious on this one. Looks like they're really moving along. And you can see the switches. Most of the switches are powered now, and the manual ones are at least monitored. This view shows the actual switch alignments in the field. If we watch closely, we might catch a switch in the act of realignment. At just the right time, Central Control gives the word, the switch obeys, and I see it on the display. It's all very neat. There are no maintained signals left on this stretch, but if there were, we'd see them here too, with their aspects.

"Let me put the headset on, and I'll show you a couple ways I talk with the system. It's cordless, you see. The keyboard's the same way. I'm not tied to one position this way. It's kind of nice to be able to lean back in my chair with the keyboard on my lap and not worry about coming unplugged. Most of my communication is data link, so the headset is really optional. I can set it to monitor all of the incoming voice channels — phone and radio both — but even then there's not a big communication load. I'll average one conversation every ten or fifteen minutes — that's on a day of heavy traffic. I talk to the machine more often than that. In the old old days, before PTC arrived on the scene, they tell me I'd have been on a voice channel fifty minutes out of every hour. Is that dispatching?

"What I like the headset for is its inertia sensors. Here's how they work. Look at the cursor on the wall display — right now it's over the on-duty time in the top left window. I activate the sensors with this button, and now my head movements direct the cursor—head to the right, cursor to the right; head downward, cursor downward, and so forth. Same idea as the old PTC trackball, only now the trackball is my head. The cursor jumps freely between displays. Once I get it where I want it on any of the four displays, I press SELECT on the keyboard, and I've made my will known to the machine.

"Let's say I want to look at the control view of a different track segment — some people still say 'planning line,' which is old PTC terminology. I nod the cursor into place over the CONTROL function—there at the bottom of the Falls City-to-Jones Junction map — and press SELECT. There's our list of track segments to choose from. Suppose we want Glen Springs to Snowden. Position the cursor, press SELECT, and there we have it — a new control area. Not a lot of traffic on this one, you can see.

"I'll show you another way of doing the same thing. Good for variety. The keyboard has a key for map selection the second function key at the top here. When I press it, I'm telling the machine I want to chose another control area for display. The machine at that point is all ears — it's just waiting to hear which area I want. I can tell it with my head, by moving the cursor in place over the area I want on the overview map. Or I can tell it with my voice, like this: 'TS one-seven-four. Over.' Saying 'Over' is the same as pressing SELECT. And there we have it Glen Springs to Snowden. Quick, isn't it?

"Let's look at the weather map. Watch what happens to the overview map when I press the last function key on the right here. There it is a weather overlay. The blue and black digital readings at stations are temperatures. Mostly blue — it's a cold morning in Wyoming. Blue is cold, red is hot, black is in between. I forget what the exact distinctions are. But the icons tell the real story. Notice the broken thermometer at Snowden, with 51 degrees in black and 11 degrees in blue. That shows there's been a 40-degree dip over the last twenty-four hours or less. That kind of swing can spell trouble for rails. You can be sure the track inspector out there has his eyes open.

"Further west, you can see snow falling at Circle, and some pretty stiff winds at Jones Junction. That icon is oriented to show the wind direction, and the numbers next to it are kilometers per hour — the 73 on top is the maximum wind velocity over the last two hours, and the 47 — well, 51 now — that's the current velocity. It's all real-time stuff, you see. With this kind of weather reporting, we can almost predict when we're going to hear from some engineer worried about maintaining his pacing speed. But of course, Central Control is always one step ahead. The pacing speeds reflect what's happening with the weather.

"I'm going to switch the weather off. Some dispatchers keep the weather overlay up all the time — build it into their user profile — but for me it makes the map a little too cluttered. I'll look at it every hour or so. Besides, if the system detects a severe condition — heavy snow, high winds, big temperature swing, or whatever — I'll get an advisory. The way things are set up, it's hard for us to miss anything really important.

"We haven't looked at the traffic plan yet. It's probably the most important thing on the wall there. The maps we've been looking at show where everything is, how close together the trains are running, whether they're moving, and so on. But they don't show how well the traffic is keeping up with the plan. To get that, I need to look at the planning graph. The idea is ancient. PTC had something similar, and back before that dispatchers sometimes played with stringlines on paper charts to try and picture the traffic flow. Quite simple, but the basic idea is sound. Our enhanced version shows all the trains on any given track segment. I tell the system which segment I want and how far into the future I want to look. I've set my default value at four hours.

"Moving up the graph, we're moving ahead in time. Moving from left to right, we're going west to east. Right now you can see a dozen or so trains running between Glen Springs and Nichols Wye. A run line that's not vertical shows a train that's moving. Here's a vertical one — eastbound 7802 is sitting in the siding at Hathaway, waiting for two westbounds to pass. The first one is Amtrak, and the second is a hotshot intermodal. They're flying. The faster the train, the less the slope on the graph.

"This solid black line divides the past from the future. Below it, we're looking at history — the run lines show exactly where each train was at any time over the last hour. We can go back further than that, but it's not real useful information — more for the archives. Above the black line, we're looking at the future — the traffic plan currently in effect. Ideally, the history segment of each run line flows right into the future segment at the black line, which represents the present. That means that right now, the train is keeping pace with the plan. That's the case with all but two of our trains here; not a bad batting average for this corridor. We've got two eastbounds a little behind schedule. You can see their run lines are yellow instead of green, and the past and future segments don't quite connect at the present. If they were in serious trouble, their run lines would turn red. I expect they'll both make up the lost time before they reach Glen Springs — we're only talking about minutes.

"We don't see a lot of red lines on the planning graph any more. When we do see one, chances are we'll need to talk with the crew to find out what's happening. Half the time, they'll call us first. Their display tells them when they're slipping on the schedule, and usually it tells them why. Things can get interesting then. The trick always is to minimize the damage. It may mean pulling the train off the main so everybody else can keep on schedule. Sometimes we may not have the siding to do that. Or if it's a hot cargo, we may handle it differently. I'll ask Central Control for a new plan — that's what the REPLAN function is for — and it will sort through the options and propose what it thinks is the best one, all things considered. Usually I'll agree with what the system comes up with — nowadays it knows practically everything. But I still have the final say.

"Speaking of the final say, I'd better stop talking. I'm just three minutes away from my shift. Time to report on duty. Highlight the current time. SELECT. There, that's more like it — now I'm getting paid for my time. Next thing is to put my workstation on standby to receive active control. To do that, I talk to the machine again."

"Hancock. Railhawk. Request standby control. Over."

"There. You can see the machine understood. Now Campbell knows I'm here, ready to go. She was probably beginning to wonder. Working at home like this, there aren't many excuses left for being late to the job.

"The instant Campbell signs off, I'm on. You can stay and watch if you like. Before long, I'll probably be looking at some live camera closeups from lead units and hyrails. We'll see with our own eyes how heavy it's snowing up there. With those weather conditions, we may get some red run lines this morning. That's when the system really shows its stuff."

This story is indebted conceptually to a fictional description of a possible interface between air traffic controllers and the ATC system of the future in "The Controller/System Interface," by H. David, published by the Eurocontrol Experimental Centre, Bretigny-sur-Orge, France, May 1986. John Vanderhorst of the Applied Communications Group assisted in writing this story.

chapter 3.0

R&D Project Development and Selection Process

At the urging of the Transportation Research Board (TRB) Committee for Review of the FRA R&D Program, FRA has developed a structured process to identify safety research areas and select specific safety R&D projects for funding. The approach consists of five logical steps, shown in Figure 3.1, which, initially were applied to the safety R&D program and are reflected in this Five-Year Plan for RD&D. Subsequently, as new information becomes available about sources of hazards, the logical steps may be followed for specific types of safety hazards to add to the list of potential safety R&D projects.

Step 1: Review of Rail Industry Historical and Potential Harm

The first step in the FRA safety R&D project development and selection process is a review of recent rail industry harm data and an assessment of causes of potential safety hazards. In this context, harm is considered to be the aggregate cost of fatalities, injuries and property damage due to rail accidents. Historical hazard data is compiled in FRA rail accident databases and accident investigation reports. The potential for future safety hazards can be understood by reviewing rail industry operating trends with expert knowledge of how railroad accidents occur.

The four relevant databases that hold historical rail incident data are the FRA's Rail Accident/Incident Reporting System (RAIRS), Highway-Rail Grade Crossing Accident/Incident Database, Railroad Injury and Illness Summary Database, and Research and Special Programs Administration's (RSPA's) Hazardous Materials Incident Database. The information in these databases is very detailed in terms of circumstances that contribute to accidents. However, these databases, typically, do not address specific causes of the hazards that result from railroad accidents or incidents.

Detailed accident reports from the National Transportation Safety Board (NTSB) and the FRA are the most important source of information, compiled by experts, about accident circumstances that contribute to hazards. While detailed investigations are undertaken for relatively few railroad accidents, the most serious accidents, in terms of hazards, have been intensively investigated and much can be learned through review of these reports, providing a deeper understanding of the characteristics of these relatively low-frequency, high-consequence events.

Finally, since accident databases and accident reports can only reflect historical accident causes and circumstances, railroad industry operational trends must also be taken into account. In this way, an understanding of causes of hazards that are not reflected in the historical databases can be developed.

Step 2: Conduct Failure Analysis

For a given accident cause or factor contributing to hazard, fault-tree logic is applied to identify specific items to be addressed by countermeasures. These specific items represent points along the accident chain-of-events at which the accident, or subsequent harm, or both, could have been prevented. Thus, the fault tree approach permits identification of multiple causes of accidents, enriching the information gleaned from the accident databases that typically assign a single, primary accident cause. Countermeasures are proposed with the goal of breaking the accident or hazard chain-of-events at the identified points. These countermeasures are advanced with an understanding of current regulatory and industry practices for the relevant area of rail operations.

- Types of possible countermeasures include:
- New or revised regulations.
- Industry standards and best practices.
- Equipment and infrastructure improvements.
- Enforcement.
- Education.

Step 3: Survey Government and Industry Countermeasures and R&D Requirements

Once specific countermeasures are identified, FRA R&D will review current and potential industry and government countermeasures to identify and assess areas of technological opportunity for R&D. That is, FRA R&D will identify countermeasures that would be enabled by R&D. For example, a potential operating rule may need research into the train speed regimes at which a particular type of train control system affords safe operation.

Step 4: Develop and Rate Individual Projects

For each countermeasure that may be aided by R&D, one or more R&D project summaries are developed to describe projects that provide information to enable the countermeasures. The project summaries are structured descriptions of projects that will be used to compare and select projects during R&D program development. Project summaries address expected outputs and outcomes, project costs and durations, as well as implementation issues for project results. Based on the project summaries, projects are then rated according to objective criteria for expected contribution to safety and likelihood of success. For a given program area, these project ratings are plotted in two dimensions (likelihood of success versus contribution to safety) to provide a high-level comparison tool for the project selection process.

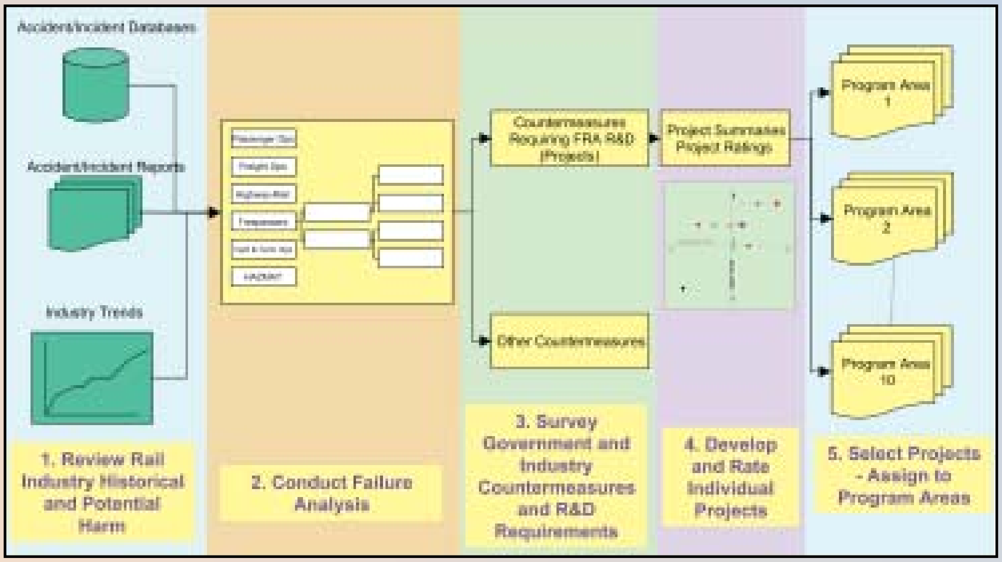
Step 5: Select Projects and Assign to Program Areas

The last step in the FRA safety R&D program development process entails selecting projects for each program area based on the two-dimensional plots and project summaries. The goal is to select the best research opportunities available to obtain the best return on investment possible from the FRA R&D budget. That is, the most highly rated projects, regardless of program area, are selected to develop budget request estimates. Once the budget has been finalized, the projects are revisited, and funding levels and schedules are adjusted appropriately. The FRA R&D budget request, for each program area, becomes the sum of the funding required for each of the selected projects in the program area.

This process, augmented by Congressional directives as well as by requirements to carry out research in direct support of rulemakings mandated by law, was used by FRA in the preparation of its FY 2002 budget request and this Five-Year RD&D Plan, and FRA anticipates that it will continue to use it in the future in the development of the R&D program.

Figure 3.1.

R&D Project Development and Selection Process



CURRENT STATUS

At the time this *Five-Year RD&D Plan* was prepared, the process described above had been applied to the Grade Crossing and Track Systems Research Program areas.

Grade Crossing Safety Research Program

Exercise of the project identification process to the Grade Crossing Research Program, which is described in Sections 4.2, 4.7, and 5.3, involved collecting accident information from the Grade Crossing Accident/Incident database. For the period analyzed (1991 through 1997) the hazard incurred from grade crossing accidents is comprised of 3955 highway user fatalities, 12,814 injuries and $130 million in highway vehicle property damage. Using accepted figures for the cost of human life and injury, this represents an aggregate hazard on the order of $14.3 billion (approximately $2 billion per year). While these figures may seem alarming, the historical data must be considered in light of the large number of crossings (260,000) in the U.S. In that context, the data would imply one grade crossing fatality every 400 years. Obviously, the likelihood of a fatality is not the same for all crossings. Review of the accident data during the course of this investigation, as well as other studies, have drawn the important conclusion that research aimed at reducing crossing accidents must realize the distinction between high-risk and the larger number of low-risk crossings. Over the last 20 years, grade crossing accidents have diminished considerably. This reduction has been achieved through application of numerous solutions. To effect further improvements in the accident record requires detailed examination of the conditions which result in accidents.

The accident information was assembled and the fault tree logic applied in order to discern primary causes and other conditions that contribute to these accidents. This step identified accident causes related to operational characteristics of crossing equipment and causes that stem from the characteristics and behavior of motorists involved in crossing accidents. Nearly 55 percent of the harm incurred in grade crossing accidents occurred at passive crossings (which account for nearly 80 percent of the crossings in the U.S.). The remaining 45 percent of the harm was the result of accidents at crossings equipped with either gates, lights (or both) or staffed by a watchman. Crossings with these "active" warning devices are exposed to the vast majority of the traffic (highway vehicles and trains).

Review of the data identified candidate research topics that included both human factors and crossing technology aspects. These topics were then logically aggregated into research projects to simplify the rating and selection process. Many of the projects identified are either ongoing or represent logical extensions to current research. Some of the projects were deemed to be better suited for implementation by other agencies. This is an important finding, since FHWA, NHTSA, and FTA in addition to FRA, carry out grade crossing research activities.

The resulting grade crossing accident mitigation projects represent three integrated themes: improve warning device effectiveness, improve vehicle driver compliance with crossing warnings, and evaluate non-traditional techniques and procedures to avoid collisions at grade crossings.

The likelihood of success and safety impact of each of the projects was assigned by an expert group. Four projects received high likelihood of success and high safety rankings. Of these, three were selected for new or continued funding. One of the seven projects with high likelihood of success and medium safety rankings was selected for new funding. Six projects with lower ranking were identified for new or continued funding.

Track and Structures Research Program

A similar strategy was applied to FRA's Track and Structures Research Program, which is described in full in Section 4.4. The historical accident information attributed to track conditions was obtained from the RAIRS database for the period 1988-1998. The RAIRS database is comprised of 356 unique cause codes, of which over 70 are track-related. This subset represents nearly 12,000 incidents resulting in 71 fatalities and nearly 800 injuries. When the over $820 million in property damage is included, the total harm for track-caused accidents exceeds $1.2 billion for the period analyzed.

The fault tree logic process was applied to the selected incidents. Over 80 candidate research topics were distilled into 37 research projects, and then considered in the context of the current R&D program. FRA's Track Systems Research Program consists

FUTURE PLANS

The project development and selection process will be applied to the remaining FRA R&D program areas. To guarantee continued success of the technique, the analysis will be revisited for each program area periodically. This maintenance will also ensure that changes in railroad operating trends are captured and considered in future R&D project development activities.

chapter 4.0

Railroad Research and Development Program

FRA R&D projects contribute vital inputs to the FRA's safety regulatory processes, to railroad suppliers, to railroads involved in the transportation of freight, intercity passengers, commuters, and to railroad employees and their labor organizations. FRA-owned facilities provide the infrastructure necessary to conduct experiments and test theories, concepts, and new technologies in support of the R&D program.

Railroad safety depends on the reliability of people, as well as infrastructure, equipment, and control systems. Railroading is known to operate in a hostile, unforgiving environment. Railroad operating workers need knowledge, training, tools, and alertness to do their jobs properly and ensure the public's, as well as their own and their coworkers' safety. Railroad infrastructure has many elements, including soil in embankments, ballast, ties, rail, rail fastening devices, turnouts, bridges, and tunnels, that must be properly designed, installed, used, maintained, and inspected if railroads are to be operated safely.

Similarly, railroad equipment has many components, including wheels, bearings, axles, trucks, springs, brakes (both air and the new electronically-controlled), underframes, draft gear couplers, safety appliances, and seats that must also be properly designed, installed, used, maintained, and inspected if railroads are to be operated safely. Train control systems, which have historically been very reliable but still enable a human being to make a mistake and cause an accident, need to be upgraded to prevent the possibility of human error from causing accidents.

Railroad transportation of passengers and hazardous materials present situations that require special attention to ensure that a high level of safety is maintained. Perhaps the greatest safety risk of all for railroads occurs at those locations where railroads intersect with streets and highways. All these topics receive specific attention in this Five Year Plan for RD&D, which addresses these issues through an appropriate combination of study, analysis, simulation, laboratory testing, and field-testing.

This chapter addresses the ten program elements that make up FRA's Research and Development Program. They are:

1. Railroad System Issues—Safety, Security, and Environment.
2. Human Factors.
3. Rolling Stock and Components.
4. Track and Structures.
5. Track-Train Interaction.
6. Train Control.
7. Grade Crossings.
8. Hazardous Materials Transportation.
9. Train Occupant Protection.
10. R&D Facilities and Equipment.

These program elements are described in detail in the following sections of this chapter. The program element descriptions are based on actual FY 2001 and FY 2002 appropriations and the President's FY 2003 Budget Request. Activities described as occurring in Fiscal Years 2004 and 2005 are contingent upon funds being appropriated to carry them out.

4.1 Railroad System Issues: Safety, Security, and Environment

This program element addresses system safety issues for freight, commuter, intercity passenger, and high-speed passenger railroads; physical and information security on all railroads; and environmental issues related to railroad operations. This system safety program undertakes research intended to enhance railroad safety from a system perspective especially for issues and topics not covered by traditional equipment or track-related research programs. Successful risk analysis methodologies and system performance metrics development are key elements to this system level approach to safety assurance and enhancement program.

Accidents sometimes result from more than one factor. Safety shortfalls and equipment or track defects frequently do not act in isolation but may be part of a combination of defects leading to an accident. Because of this, a system safety approach must be used in analyzing the cause of an accident and developing mitigation measures.

Why a Priority?

Since the formation of the U.S. Department of Transportation in 1967, improving the safety of the transportation system in the United States has been one of its strategic goals. Within FRA, continued research and evaluation of high-speed rail technology has supported the successful introduction of new high-speed Acela Express services on the Northeast Corridor by Amtrak. As the full complement of train sets is introduced into service, the FRA needs to ensure that a systems approach continues to be taken to track the safety issues associated with this deployment of new and innovative technologies in the traditional railroad environment (freight, intercity and commuter) as well as in dedicated high-speed ground transportation services.

The recent derailment and fire involving a freight train in a tunnel under Baltimore have raised issues regarding aging railroad infrastructure, bottlenecks in the railroad network, the routing of hazardous materials, and management of information flows when emergencies occur. Both the U.S. Congress and the press are calling for additional research on all of these issues.

In addition to safety, the issues of physical and information security assurance are also a key element of USDOT policy. The terrorist events of September 11, 2001, have made security issues even more important. Presidential Decision Directive (PDD) 63, “Critical Infrastructure Protection,” requires federal agencies to “take all necessary measures to swiftly eliminate any significant vulnerability to both physical and cyber attacks on our critical infrastructures, including especially our cyber systems.” PDD 63 defines critical infrastructures as “those physical and cyber-based systems essential to the minimum operations of the economy and the government.” Rail transportation is part of this critical infrastructure of the nation and needs to be protected from both cyber and physical attacks. Vulnerability assessments of railroad systems are needed to identify and evaluate potential cyber attacks, terrorist attacks, and bomb threats. Research is required on how best to apply the latest physical and information security technologies to the railroad environment. Evaluation of detection technologies for chemical, biological, and other weapons, is also needed for the safety of the railroad system for employees and the public.

Research is also needed to address environmental issues associated with railroad operations such as noise, fuel consumption, air pollutant emissions, and electromagnetic field effects. FRA will enhance the environmental friendliness and the competitiveness of the railroad industry by research into and development of promising fuel and engine technology and advancing specific innovations showing exceptional efficiency and environmental benefits.

Objectives

The objectives of this program element are: to support the rulemaking activities of the Office of Safety by providing timely and comprehensive analyses and test data; to identify and categorize risks associated with railroad operations and undertake research and development activities aimed at minimizing those risks; to identify potentially adverse environmental impacts of railroad service, especially for commuter and high-speed rail, to the communities through which it travels and to develop means to both mitigate such impacts and for more accurate comparisons to the "no-build" alternatives; and to reduce the threat of damage to the railroad system and injury to train employees and the traveling public as a result of acts of terrorism and vandalism.

Research projects are organized within the following focus areas: contextual research, system safety, security of railroad systems and infrastructure, and environmental issues.

Expected Outcomes

Major outcomes of this program component will be the development and enhancement of general assessment methodologies for system and component level risk assessments. An outcome in this area will be new or revised performance-based federal safety regulations and industry standards and recommended practices for commuter, intercity, and high-speed passenger equipment. Improved detection methods for railroad system safety and security, potentially using technologies developed for other security programs, will be another outcome. Standardized evaluation methods and assessment criteria to address noise as a source of public concern—a critical part of any rail-oriented project's environmental impact statement (EIS)—will be another outcome. This research will also have the outcome of advancing and transferring to the private section those promising new technologies to reduce pollution and to improve energy efficiency of locomotives.

Project Descriptions

CONTEXTUAL RESEARCH

As noted in Chapter 1, the past seven years have seen radical changes in railroad industry structure and operations. Some parts of the railroad industry are beginning to test new ways to approach the challenge of reestablishing a stable institutional structure while building capacity and increasing operational efficiency for the future. FRA needs to continue examining alternatives for the future structure of the freight, intercity passenger, and commuter railroad industry, including the effects of a growing interest in joint public and private ownership of railroad infrastructure and whether or not a freight railroad duopoly is in the public interest.

The TRB Committee for Review of the FRA R&D Program recommended that FRA undertake such contextual research so that issues can be anticipated and addressed in the R&D program in the context of technological developments and organizational and operational changes of the railroad industry. FRA's R&D program managers currently review trends in the railroad industry and other industries to anticipate when and where technology improvements may be introduced. Some examples of emerging trends include the increased use of new and innovative types of intermodal equipment, the increasing axle loads for freight equipment, the growth in shipments by rail of chemicals and spent nuclear fuels, the expansion of cross-border traffic as a result of NAFTA (especially intermodal), the growth in area and reduction in density of U.S. cities, the increasing containerization of international trade, and the growth of e-commerce. Research on the context of the railroad of the future in the overall U.S. and international transportation enterprise is needed to improve the entire safety R&D process. This research will include assessments of new technologies and equipment (including information technology), traffic flows and flow forecasts, the competitive environment for both freight and passenger business, strains on capacity, the relative mix of commodities in freight traffic, the mix of passenger and freight service, railroad mergers and spin-offs, and changes in public policy concerning intercity passenger and commuter rail operations.

As part of the FRA's effort to better understand the complex nature of the "new" railroad operational environment, innovative analytical approaches such as "system dynamics" will be reviewed for possible application. The goal is to find tools that help bring a new perspective and a better understanding to how the industry operates and adapts to a fast changing environment. The result will be a better understanding of the cause and effect elements of organizational behavior at work in the railroad industry. Thus, FRA would be able to assess the likely impact and effectiveness of different policies and decisions on railroad industry growth, stability, safety, and behavior. Analyses would show how investments in PTC, other Intelligent Railroad Systems, and new intermodal equipment technologies could affect railroad and highway safety and well as the financial health of the railroad industry.

Last year, the USDOT Working Group on Enabling Research identified some enabling technologies for transportation. They include improved understanding of human performance and behavior; new computer, information, and communications systems; advanced material and structural technologies; energy, propulsion, and environmental engineering advances; sensing and measurement technologies incorporating nanotechnology; and analysis, modeling, design, and construction tools. FRA will continue to evaluate all these technologies for application to the railroad environment and operations.

This Working Group also saw many challenges and opportunities for transportation in 2025. They include changing demographics, economic growth and globalization, urbanization and modernization, safety and security of the global transportation system, the digital world of information technology and telecommunications, and transportation sustainability. Many of these challenges and opportunities will clearly be realized by the railroad industry in the future. FRA will address these issues throughout the five years covered by this Plan.

RAILROAD SYSTEM SAFETY

Passenger Rail Safety Assessments

This project area will support the Office of Safety in the continued development, revision, and use of waivers for all system elements of passenger rail operations. Topics covered include system-level items such as emergency preparedness planning and evacuation requirements, fire safety requirements, and the update and refinement of passenger equipment safety regulations and track safety standards. It will also continue to provide the necessary technical assessment and safety validation of new high-speed services, such as Amtrak's Acela Express, that have been initiated under new regulatory efforts. In addition, projects related specifically to high-speed grade crossing safety are addressed in the Next Generation High-Speed Rail Program and are described in Chapter 5.

A core group of technical experts from numerous engineering disciplines will evaluate the safety of any proposed new high-speed rail systems and technologies, including maglev, that are not covered by existing safety regulations. Disciplines cover vehicles, track, vehicle/track dynamics, communications, control and automation, construction and operation, human factors, and overall system safety. Current programs requiring varying levels of this support are the aforementioned projects, the Next Generation High-Speed Rail Program, and the various working groups chartered under the RSAC and APTA's Passenger Rail Equipment Safety Standards (PRESS) development effort.

Detailed Accident Analyses

During FY 2002, a project to collect selected railroad accident data will be initiated. The focus of this work will be to gain insight into the usually complex web of events and actions that lead to major railroad accidents. The goal of each accident analysis will be to develop and document an in depth understanding of the complex interactions between both the technical components of the system and the operators and users of the systems. The knowledge gained from these investigations will be utilized as an input into the ongoing effort to effectively develop R&D initiatives. Some findings from this research will be able to be applied directly to certain regulatory development initiatives.

Shared Use of Track and Right-of-Way

Commuter railroads and transit authorities face constraints in the availability of capital to construct new systems to handle increasing growth in ridership. The use of existing railroad rights-of-way and track has become an important part of their strategy to initiate new commuter rail services while minimizing capital outlay. FRA intends to work together with FTA and APTA to undertake risk assessments regarding the shared use of track or right-of-way by passenger trains and freight trains. Activities of the two agencies to develop crashworthy self-propelled commuter rail vehicles are described in Section 4.9.

Planning Efforts

The number of States that are considering high-speed passenger operations continues to increase. FRA provides support to these States with information on the operational safety of proposed high-speed ground transportation systems, the safety record of equipment currently under consideration or under development, capital and operating costs, and traffic forecasting techniques. This is an on-going activity.

Performance-Based Regulations

The TRB Committee for Review of the FRA R&D Program has recommended that FRA's safety regulatory process embrace the establishment of performance-based regulations, and that the Office of R&D support FRA's safety mission by conducting research on the establishment of and transition to performance-based regulations. The TRB Committee was concerned that current FRA regulations could inhibit the implementation of new technologies by the railroad industry. As a first step, FRA intends to study how other USDOT administrations and other parts of government and industry have approached modifying their regulatory procedures and processes. The John F. Kennedy School of Government at Harvard University is helping FRA determine the feasibility of adopting performance-based regulations, and evaluate them to see if they allow for easier adoption of new technologies and operational approaches while ensuring existing or higher levels of safety are assured. In FY 2002, the focus will be completing the review of approaches and then to move on to how best to apply the experience of other organizations to the FRA. Key stakeholders within FRA will be included in this process. In addition to addressing the topics of enforcement and safety assurance in general, the need for adequate safety monitoring metrics and early intervention tools to ensure safe operations will be covered.

Intelligent Weather Systems for Railroad Operations

Some recent accidents and derailments have been attributable to adverse weather conditions; flash floods, mudslides, and avalanches have caused derailments and deaths. In addition, hurricanes and tornadoes pose a threat not only to railroad operations, but to railroad personnel and passengers as well. As noted in Chapter 2 of this Plan, Intelligent Weather Systems are a component of Intelligent Railroad Systems. FRA intends to examine ways that weather data can be collected on railroads and moved to forecasters, and ways that forecasts and current weather information can be used by railroad control centers and train and maintenance crews to avoid potential accident situations. In FY 2002 and beyond, work will concentrate on addressing feedback received during a symposium on this topic held in early FY 2002. This research is estimated to continue for 5-6 years after it begins.

Wiring Safety

The National Science and Technology Council has identified wiring safety as an issue of national concern in a number of sectors of the economy, including power generation, power transmission, housing and factories, and transportation, including aviation, transit, and railroads. This past year, FRA participated in the Interagency Working Group on Wire Safety Research. FRA will now apply the results of this working group to focus its research to identify potential problems raised by aging wiring in connection with railroad signaling, communications, train control, electrification, and propulsion. This activity will be coordinated with the AAR, ASLRRA, APTA, RPI, and Amtrak, as well as the academic community.

The principal wire safety issue facing FRA is associated with the catenary wire that provides power to passenger trains along Amtrak's Northeast Corridor. The issue is the fatiguing of the catenary wire from the passage of pantographs on hundreds of trains a day over a 70- to 90-year period. Even though copper is a very ductile metal, it ultimately reaches a limit at which fatigue cracking takes place. Other components of the 25 Hz generating and transmission system are failing also, and replacement parts are no longer commercially available.

Joint research between FRA and Amtrak has identified the feasibility of using nondestructive ultrasonic inspection of catenary wire. Future activities will focus on an evaluation of alternatives to ultrasonic inspections and will develop and field-test a prototype inspection system for the nondestructive evaluation of catenary wire. This research is to be completed in FY 2003.

SECURITY OF RAILROAD SYSTEMS AND INFRASTRUCTURE

The U.S. railroad system is an essential infrastructure, carrying more than 40 percent of the ton-miles of freight in the United States. Critical to the Nation's economy, the Nation's railroad system is also critical to movement of military-essential equipment when deploying U.S. forces overseas. Railroads are becoming ever more dependent on cyber systems (see Chapter 2, Intelligent Railroad Systems) to improve their operational efficiency and safety and to serve their customers better. The railroad industry invested nearly $200 million to successfully ensure that the Y2K problem would not interfere with its operations.

Industry consolidations and the resultant centralization and inter-connectivity of communication, dispatching, and business-critical database functions place greater risk on these mission-critical systems of cyber-based attack and exploitation. Customer-driven focus on web-based shipment tracking, just-in-time delivery, cross-border mergers, and increased dependence on electronic commerce and data exchange, all raise the vulnerability of the railroad industry to cyber attacks.

The physical vulnerability of the U.S. railroad network is of concern, especially in light of the terrorist attacks in New York and Washington in September 2001. The railroad bridges across the major U.S. rivers, as well as the tunnels in the western mountains and in Baltimore and New York, will be examined to better understand potential risks and mitigation strategies to losses of one or more of these links to the movement of intercity freight and passengers.

The USDOT and AAR currently have a partnership agreement and will continue working together to identify vulnerabilities, share threat information, and develop a joint plan to protect the Nation's railroad system from intentional disruption. The partnership effort will help raise awareness of threats and vulnerabilities to the nation's rail industry and their intermodal partners, and develop strategies to address those threats. With the growth of intermodalism and electronic interconnectivity of the nation's transportation system, cooperation among all modes of transportation will become vital, both to the nation's security and its economic well being.

The AAR has established a transportation Information Sharing and Analysis Center (ISAC) where industry members can share security information, especially about ongoing information system attacks. The ISAC serves as a clearinghouse for receiving, analyzing and distributing critical data needed to protect vital information systems. The ISAC works closely with ISACs established for other critical infrastructure sectors, such as Banking and Finance and Telecommunications, as well as the National Infrastructure Protection Center. FRA will look for opportunities to work with the AAR and the various railroads in their efforts to prevent criminal attacks against the railroad system.

The visibility of the new Acela Express high-speed passenger train service in the Northeast Corridor, accompanied by the extensive regional advertising campaign for this new service, may, by drawing attention to these and other passenger trains, have the unintended effect of increasing the vulnerability of all passenger trains to those intent on causing damage or harm. Airline and airport-type security arrangements will be examined for their applicability to trains and railroad stations.

In security, research in micro-electro-mechanical systems (MEMS), and nanotechnology, could improve the detection of trace/bulk explosives, chemicals, and biological weapons. Current detection technology is expensive, large, and often not as sensitive or selective as needed. MEMS could provide sensing technologies that are more sensitive, selective, abundant, and reliable than those currently used, while also being cheaper and lighter. Moreover, multiple MEMS sensor technology offers a solution to the problem of false positive alarms. FRA will evaluate the work being performed by FAA on MEMS to determine their application to railroad security.

FRA plans to initiate research regarding the application of security technologies to railroads. Portable bomb/explosive detection and trace technology will be explored for potential use to detect such hazards on the Nation's railroads, particularly passenger trains. Advanced railroad yard trespasser detection technology will also be researched. FRA plans to assess the potential consequences of a cyber attack on the railroad system of the U.S. in concert with the national effort to increase the security of critical infrastructures. These efforts will be coordinated with other modes in USDOT to ensure the railroad industry takes advantage of promising technologies. Some in-house efforts on railroad security were started during FY 2000 and this work is expected to continue for 5 to 10 years.

ENVIRONMENTAL ISSUES

FRA R&D on environmental issues is driven by the phase-in of the Environmental Protection Agency's (EPA's) more stringent locomotive emissions standards and by increasing public concern with transportation noise. Research will include compilation of a database on environmental performance characteristics of existing and advanced rail systems, to enable assessment of trade-offs in deploying alternative fuels and locomotives (turbines, electrics, diesel-electrics) and the optimization of environmental performance and energy efficiency at reasonable cost. Environmental characteristics of interest will be base lined and documented in a comprehensive FRA database by technology type and generation (fuel type, locomotive propulsion power and weight loading ratios, track quality, etc). This knowledge base will serve to inform the EPA, railroads, transportation planners, and the public regarding environmental compliance for railroad operations, and to inform FRA policy and regulatory decisions, as well as assist railroads in improving efficiency, economics, and environmental compliance.

Noise Identification and Mitigation

Noise is a concern to the surrounding community where trains operate and to the crews who operate them. Trains stopped in cities and suburban areas due to rail line congestion have become a growing noise problem. Railroad noise can come from a variety of areas, the vehicle itself (aerodynamic noise), or specific components of the vehicle such as traction motors, motor blowers, wheel squeal, brakes, and horns. There is a need to measure, assess, and find reasonable means of mitigating railroad noise. Noise from classification yard impacts must also be addressed. New friction modifiers can help mitigate noise from many of these sources.

The mitigation of noise from high-speed rail operations is a special area of concern. Mitigation potentially is expensive and could be an impediment to high-speed system deployment. These problems might directly affect operating crews, passengers, and property owners adjacent to these new technology systems. Evaluation methods and assessments are needed to address noise as an unresolved source of public concern that has become critical to successful high-speed rail implementation.

Electromagnetic Fields (EMF) and Radiation (EMR) Evaluations

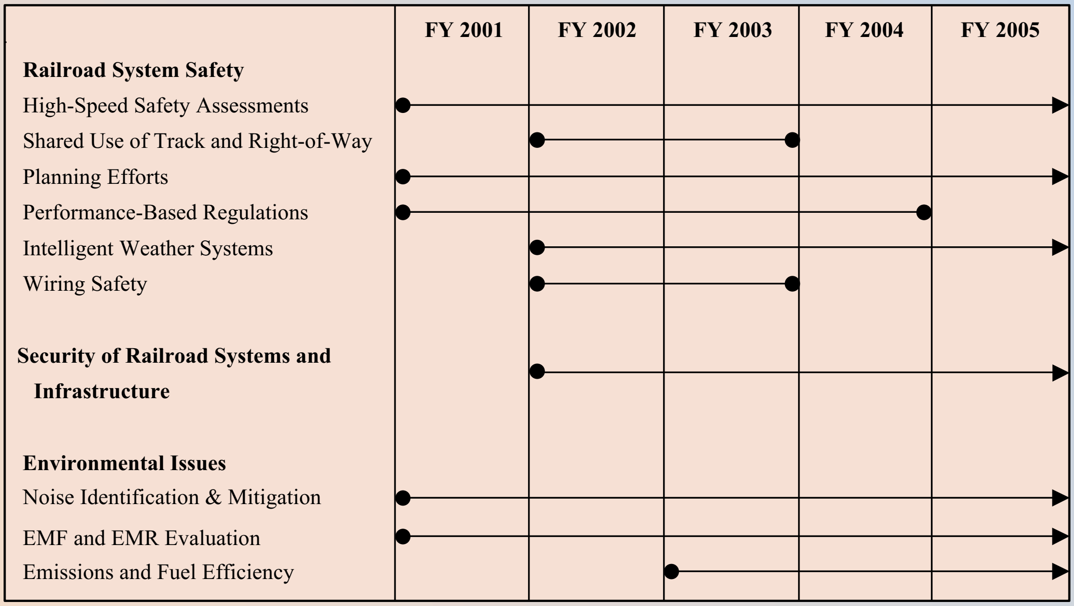
EMF and EMR effects, as well as their measurement, prevention, and mitigation, will be ongoing issues for rail transportation systems for the foreseeable future. It is the intent of FRA to stay current on developments in this complex field and by applying advances made by others conducting primary research. EMF and EMR expertise will be maintained at the Volpe Center. EMF and EMR measurements of new ground systems such as maglev will continue to be made to put their EMF and EMR effects into the proper context.

Exhaust Emissions Reduction and Energy Efficiency

Just as the Federal Government is supporting a major initiative to reduce exhaust emissions and improve the energy efficiency of truck engines, a similar initiative is needed to bring new technology to the railroad industry to reduce pollution and energy consumption. FRA is working with the Department of Energy (DOE) to establish a program to enhance the environmental friendliness and the competitiveness of the railroad industry by transferring promising fuel and engine technology from the trucking initiative and by advancing specific innovations showing exceptional efficiency and environmental benefits. A wide range of technologies that could improve energy efficiency and reduce environmental effects of railroads will be assessed. The technologies include: advanced electric traction motors; advanced diesel and gas turbine engines; fuel cells; pollution control systems; alternative fuels, including clean diesel and natural gas; in-situ measurement technologies for exhaust gas analysis; on-board and wayside rail lubrication systems (discussed in Section 4.5); and energy management systems, locomotive health monitoring systems, and tactical and strategic traffic planners (described in Chapter 2, Intelligent Railroad Systems).

Table 4.1

Planned Timeline For Railroad System Issues: Safety, Security, And Environment



4.2 Human Factors

Human factors accidents occur in the railroad industry in two primary areas: train and maintenance operations, and grade crossings. Operating practices R&D projects address human factors accidents in yard and terminals and in mainline train and maintenance operations. The grade crossing elements of the Human Factors program address the effectiveness of warning and barrier systems at grade crossings, on trains, and in motor vehicles that can reduce accidents. The Human Factors program element provides analytical and technical direction and support to reduce the number of accidents, deaths, and injuries due to human error, and to reduce the rate of railroad employee-on-duty fatalities, injuries, and illnesses.

The Human Factors program element also supports the concept of Human-Centered Transportation Systems, which presents an approach to the design, development, and implementation of technologies to improve transportation system safety, reliability and productivity. The "human-centered systems" approach focuses on human capabilities and limitations with respect to human/system interfaces, operations and system integration. Increased attention to human performance and behavior will reduce crashes, loss of life, injuries, property damage, and resultant personal and financial costs. All the projects described below incorporate the "human-centered systems" philosophy in their design and seek to further the use of scientific information about human behavior and performance to reduce railroad accidents.

Why a Priority?

Since 1985, human factors accidents have accounted for approximately one-third of all railroad accidents and half of all yard accidents. In 2000, 1147 human factor-caused accidents occurred, which were 38 percent of the total accidents.

The reduction of human factors accidents requires examination of current railroad operating practices and, given industry trends, anticipation of the future safety of current practices. Yard and terminal accidents may be caused by shortcomings in operating practices that include the methods and materials that are used to train and test employees in the performance of their jobs, the methods and materials that are used to perform specific jobs and tasks, the rules that govern job and task performance, and the general interaction of employees with the job environment and supervisors. Operating practices can result in human factors accidents for a variety of reasons. For instance, lack of training may cause accidents because the training methods are inadequate or inappropriate, or because the training materials lack readability or are inappropriate for the education level of the employees, or because the testing methods are lax. Disproportionate numbers of human factors accidents in specific job categories or environments currently provide the best indication that operating practices should be critically examined.

Operator fatigue, especially when it involves locomotive engineers, can have catastrophic consequences. However, the number of human factors accidents that have root causes in fatigue is not known. Railroad operations occur 24 hours a day and work schedules are not always predictable. Unlike workers in most heavy industries that have 24 hour operations, the Federal Hours of Service Act sets limits on the maximum number of on- and off-duty hours for railroad operating employees. However, accidents and injuries may still be attributable to the workload, stress, and fatigue allowed by work schedules that comply with the Hours of Service Act.

New technologies have been developed that hold promise for the measurement, detection, and/or prediction of workload, stress, and fatigue. Several projects in this program are designed to provide the necessary information about the effects of railroad work schedule characteristics on workload, stress, and fatigue to allow the selection of those solutions best suited to the current state of the railroad industry. The FRA recognized the potential for Hours of Service compliant work schedules to generate fatigue-induced accidents and injuries and, as a result, initiated the Engineman Workload, Stress, and Fatigue project. Crew scheduling, one of the components of Intelligent Railroad Systems described in Chapter 2, is expected to have a major impact in reducing fatigue among train crewmembers.

Consideration must also be given to future changes in the industry and the implications of such changes for workload, stress, and fatigue caused by work schedules. For instance, mergers, mixed freight and passenger traffic (possibly high-speed), and the consolidation of dispatching offices results in fewer dispatchers controlling larger territories by more use of advanced technologies and computerized aids. At present, researchers do not know whether current dispatcher work schedules and conditions are causing critical workload, stress, and fatigue problems. They also do not know whether increases in dispatcher responsibilities will increase workload, stress, and fatigue and whether changes in work schedules, technology, and computerized aids will decrease or increase those effects.

Grade crossings present a major hazard to motor vehicle drivers, as well as pedestrians, and are the greatest cause of fatalities and injuries in the railroad industry. In 2000, there were a total of 3,502 incidents at public crossings, resulting in 425 fatalities and 1,219 injuries. Many grade crossing accidents are directly due to motorist and commercial vehicle operator behavior. The majority of accidents occurred at passive grade crossings and it is not surprising, then, motorists and commercial vehicle operators not stopping caused that 53 percent of accidents. However, in many situations the flashing red lights were ignored. In 10 percent of accidents, the motorists and commercial vehicle operators actually went around or through lowered gates. Why motorists and commercial vehicle operators would take such risks is unknown, but motivations will be examined through several research projects over the next several years, which builds upon the research now underway.

Finally, because human factors related accidents and injuries account for such a large proportion of overall incidents, it is imperative that periodic evaluations be conducted to assess program strengths and weaknesses and provide direction for future improvement. Both internal and external factors that affect or influence the overall success of the Human Factors Program should be included in that assessment.

Objectives

Yard and Terminal Safety

The primary objective of the yard and terminal research is to determine the human factors aspects of railroad yard and terminal operations that can be changed to enhance safety. This research includes the manner in which specific jobs are performed, the design of the tools that are required to perform the job, and the circumstances in which the job is performed.

Train Operations Safety

The objective of the train operations safety research is to assess the current problem of operator fatigue within the railroad industry and to cooperate in the development of the tools to enhance safety. The primary focus will be to determine whether common work schedules encountered in railroad operations produce sufficient fatigue, lack of alertness, or stress in locomotive engineers and dispatchers, to compromise the safety and efficiency of their work performance. Related questions concern the amelioration of such fatigue and stress by adjustments in work schedules, crew calling procedures, hours of service regulations, and the exacerbation of fatigue by high-speed operations. The impact of emerging technologies (e.g., digital communications, computers, and GPS) on human performance and safety is also addressed.

Grade Crossing Safety

The objectives of the grade crossing human factors research are:

- Improve knowledge of driver behavior.
- Improve driver warning systems, both visual and audible.
- Improve knowledge of opportunities to reduce speed-related risks at high-speed crossings.
- Evaluate Intelligent Transportation System concepts for grade crossing safety.

Program Evaluation

The objectives of the Program Evaluation effort are:

- To assess the overall need for Human Factors research in railroad operations.
- To develop specific performance goals and objectives based on the overall needs of the industry.
- To develop a plan for implementing recommended improvements that will help achieve these program goals and objectives.
- To develop performance indicators to be used in assessing the outcomes of the Human Factors Program.
- To improve the overall effectiveness of the Human Factors Program.

Expected Outcomes

The Yard and Terminal Safety program plans to:

- Identify and modify unsafe operating practices in yard, terminal, and maintenance-of-way operations.
- Identify and modify ergonomic causes of yard, terminal, and maintenance-of-way injuries; and apply the Behavior-Based Safety Process.

The Train Operations Safety program plans to:

- Enhance the understanding of the consequences of fatigue in locomotive engineers, dispatchers, and other operating personnel with regard to Hours of Service regulations, vigilance monitoring, high-speed operations, and rapid workload transitions.
- Identify strategies for the formation of effective teams among groups of operating personnel. Analyze cognitive tasks and strategies for safely incorporating new information display technology and digital communications into the railroad environment.
- Develop guidelines and recommendations for design and evaluation of computer-aided and communication tools that support operating personnel.

The Grade Crossing Safety program plans to:

- Increase public awareness of hazards at grade crossings through improved driver education programs.
- Develop strategies to change risky behavior in motorists and commercial vehicle operators by understanding how they perceive risk and why they take risks that cause accidents.
- Develop strategies to aid motorist decision-making during critical commuting periods.
- Enhance understanding of human factors safety implications of intelligent grade crossing technology.
- Improve motorist and commercial vehicle operator perception of train location through

optimal acoustic warning systems.

- Develop strategies to increase motorist and commercial vehicle operator acceptance of innovative warning systems.
- Enhance understanding of the effects of grade crossing accidents on locomotive engineer performance and the effectiveness of standard counseling techniques.

The Program Evaluation effort plans to:

- Identify key factors and resources needed, both internal and external to the agency, for achieving Human Factor Program goals and objectives.
- Improve the feasibility of conducting Human Factors research in railroad operations.
- Improve the utilization of Human Factors research results.
- Measure the impact of the Program Evaluation effort.
- Improve the overall effectiveness of the Human Factors Program.

Project Descriptions

YARD & TERMINAL SAFETY

One-Person Remote Operations

Devices to remotely control locomotives in industrial settings, such as steel plants, have been in use for nearly twenty years. Until recently, the use of these devices was not a concern to the FRA since these industrial operations do not fall under FRA jurisdiction. However, in the early 1990's several railroads began to use this technology in yard operations that are within FRA jurisdiction. This technology has the potential to increase productivity and reduce labor costs by enabling a one-person crew to perform all of the functions that were previously performed by a two-person crew. However, there are concerns that this increase in productivity will also degrade safety due to increased workload and fatigue, and other human factors issues. This project will assess the change in accident/injury risk associated with remote operations relative to normal yard operations. This project started in FY 2001 and is to be completed by FY 2003.

Ergonomic Issues and Root-cause Analysis in Yard & Terminal Injuries

Analyses of railroad supplementary injury and illness records in the Yard and Terminal Injury Evaluation project (completed in FY 2000) indicated that 25 percent of all injuries were due to trip/slip hazards, 23 percent were due to muscle strains, and 11 percent were due to lifting injuries. The Yard and Terminal Injury Evaluation project addressed the immediate causes of these injuries due to employee complacency and/or inadequate training, supervision, and safeguards. A follow-up, root-cause analysis of these injuries will now be performed to identify the chain-of-events that led to the immediate cause of the injury. Individual, environmental and managerial factors will be examined to formulate countermeasures to prevent the recurrence of similar injuries in the future. Some of these injuries may be due to poor ergonomic design and are preventable. This project will identify injuries with ergonomic causes and suggest means to remediate those causes. Among the topics to be addressed are switch stands, hand brakes, and belt packs used for the remote control of switching locomotives. This project (as did its predecessor, Yard and Terminal Injury Evaluation) also provides support to the Switching Operations Fatalities Analysis (SOFA) Working Group which has been examining the contributing factors to fatalities and serious injuries in switching operation. The project started in FY 2001 and is projected to continue until FY 2005.

Maintenance-of-Way Safety

Annually, approximately 10 percent of all on-duty casualties of railroad employees occur during maintenance-of-way operations. As is the case for yard and terminal casualties, anecdotal evidence indicates that there are four primary reasons for many of the incidents leading to these injuries: (1) employee complacency leading to inattention to safety considerations while performing familiar tasks, (2) inadequate training, (3) inadequate supervision, and (4) inadequate safeguards built into procedures and equipment. The safety implications of fatigue will be a particular focus of this project. This project will identify improvements to reduce employee injuries and enhance safety. The project began in FY 2001 and is due to be completed in FY 2003.

Railroad Safety Culture: Behavior-Based Safety Process and Safety Rules Consolidation

Two projects are using the Behavior-Based Safety (BBS) Process, which applies behavioral analysis methods to attain continuous improvements in safety in industrial settings, to improve safety and change railroad safety culture. The BBS methodology identifies and observes safety-critical behaviors to provide positive peer-to-peer feedback for long-term, continuous improvements in safety. This approach has significantly reduced injury rates in many other industries. The success of this approach is not only driven by the systematic reduction of at-risk safety behaviors through peer-to-peer observation and feedback, but also by the systematic identification and mitigation of those organizational barriers (work environment factors, policies, procedures, etc.) which may stand in the way of reducing at-risk behaviors. Positive communication processes help establish commitment in the process at all levels of the organization, from senior managers to front line employees, often resulting in long-term changes in the "safety culture" of the organization.

The Consolidation of Safety Rules project is another approach to improving railroad safety culture. Hundreds of safety rules written in the early 1900's are outmoded and do not function well with the existing needs of modern railroading. On some railroads, outmoded safety rules have been identified as an organizational barrier to improving railroad safety. It is widely believed that these outmoded safety rules, in conjunction with a punitive disciplinary process, result in a "blame cycle" between management, labor unions, and employees and often discourage the identification and elimination of unsafe behaviors in the workplace. The overall goals of this project are: (1) to consolidate outdated safety rules into critical safety rules and guidelines for safety, (2) to write general safety rules and guidelines focused on safety-related behaviors rather than situation-and-site specific rules, (3) to include input from labor unions and line staff in the development of a new user-friendly safety rule book, (4) to utilize this Safety Rules Consolidation Project as a means of effecting positive change in safety culture. The BBS process will be used to attain these goals, and the recently established Safety Assurance and Compliance Process in FRA's Office of Safety, a non-punitive partnership approach between the Federal government, railroad management and railroad labor, will assist in implementation. These projects began in FY 2001 and are scheduled for completion in FY 2004.

TRAIN OPERATIONS

Fatigue Tools

This project will develop tools to help detect, manage, and mitigate fatigue in railroad operations. The tools will be developed from fatigue models developed for the U.S. Air Force by Science Applications International Corporation (SAIC), and for the Australian Railroads by the University of South Australia. A minimum of two products will be developed: software and a protocol for determining the role of fatigue in accidents; and software for determining the fatigue produced by a schedule of work. Other tools may include software to analyze the fatigue-mitigating effects of napping strategies, and software to predict future individual alertness levels given a particular work/rest schedule. This project began in FY 2001 and is scheduled for completion in FY 2005.

Human Reliability Analysis in Positive Train Control

The reliability of complex systems is now a routinely analyzed aspect of systems engineering. However, while reliability analyses have been routinely performed on electrical, mechanical and chemical systems for many years, it has only recently been recognized that to minimize the probability of system failure, human reliability must also be considered. This project will, in consultation with the Office of Safety and the Railroad Safety Advisory Committee (RSAC) on Positive Train Control (PTC), determine the critical human failure modes in emerging PTC technologies and quantify the human failure probabilities. This project is currently examining the Communications-Based Train Management system of CSX and is expected to continue into FY 2005.

Engineman Vigilance Monitoring

This project will explore recently developed technology to continuously monitor locomotive engineer alertness in real time. It is well known that people are not capable of accurately assessing their own level of fatigue and alertness. Devices that can monitor a person's alertness in real time can be used to inform that person that they are at risk for falling asleep in the near future, thereby avoiding the use of faulty personal judgement. The first phase of the project will identify those technologies that appear to have promise for use in the locomotive cab environment. The devices should have demonstrated capacity to detect declines in alertness, be unobtrusive, and have user acceptance. At this time, several devices are under consideration for use in the second phase that will test the devices with locomotive engineers. The project is in progress and should be completed in FY 2002.

Dispatcher Readback/Hearback Training

Human error, including incorrect or inadequate communication, is a causal factor in many accidents. The job of a railroad dispatcher requires extensive verbal communication with train crews and other track users. "Readback/Hearback" refers to the process that a dispatcher and a track user employ in communicating instructions regarding authority for a train, inspection vehicle or track crew to occupy a specific segment of track. This process is intended to prevent miscommunication but its success depends upon the skill of the dispatcher. Air traffic controllers, who perform functions similar to that of railroad dispatchers, use similar procedures. The FAA Academy developed a training module: "ATC Communications," to improve readback/hearback skills in air traffic controllers. These course materials will be analyzed and converted for use with railroad dispatchers. An evaluation process will be developed to assess training effectiveness, and printed course materials and videotape will be disseminated to railroad training organizations. The project is in progress and is scheduled for completion in FY 2002.

High-Speed Operator Stress and Fatigue

This project examines workload, stress, and fatigue issues within the special context of high-speed train operations to determine if there is a relationship between train operating speed, sleep loss, and work-rest cycles in producing operator fatigue. High-speed railroad operations cause forms of fatigue and stress that differ markedly from those due to circadian rhythms, sleep loss and work-rest cycles. High speed operations can affect the locomotive engineer in two ways: first, as speed increases, locomotive engineers are exposed to increasing sensory loads because they must scan the track and its fast-flowing vicinity with increasing intensity to detect signals and dangerous situations. Second, the process of information retrieval (track characteristics, landmarks, the Daily Operating Bulletin, operating rules, etc.) from the locomotive engineer's memory becomes increasingly intensive with increased speed. Therefore, as speed increases, the workload of information processing and retrieval increases. The project uses the high-speed locomotive simulator developed cooperatively with the Volpe Center and Massachusetts Institute of Technology (MIT) to simulate various information loading scenarios for both locomotive engineers and dispatchers. This project is currently in progress and is expected to continue through FY 2003.

High-Speed and Freight Locomotive Simulator Research Program

With the mechanical failure of the its locomotive simulator in Chicago, FRA will need to either purchase or lease a locomotive simulator to meet FRA's research requirements. With the introduction of high-speed rail operation in the U.S., there is also a need to evaluate human factors issues related to high-speed passenger operations. In FY 2000, FRA initiated a project to evaluate the functional capabilities of Amtrak's Acela high-speed training simulator for use as a research tool. Design modifications were then proposed which would allow the Acela simulator to function as a research tool. As a research tool, however, the Acela simulator would be mostly limited to research on high-speed operations and other cross-cutting issues that bridge both high-speed passenger operations and lower speed freight operations. Consequently, additional options were proposed as part of this study for the design of a research facility capable of simulating different types of locomotives and systems operations (freight operations, passenger operations, PTC systems, communications systems, in-cab displays, etc.) and evaluating the impact of those systems on locomotive engineer performance. There are four functional areas that could be supported by a research facility that included various types of simulation, modeling and computer-aided design: (1) human factors and operations safety, (2) track structures, materials and configurations, (3) train dynamics, and (4) advanced technologies.

Human factors and operations safety simulation research could support research into safety, usability, user acceptance, and efficiency of various railroad operations technologies, training methods and procedures in a safe environment without risk of injury or property damage. A locomotive simulator, along with a computer-aided design (CAD) software and supporting technologies could be used to design and test track structures, materials and configurations before any ground is broken or track is laid, enabling safe and cost-effective design and analyses. An interdisciplinary simulator research facility could also address train dynamics issues, by studying and modeling different train consists, draft/coupling technologies, and in-train forces to understand how different train dynamics models have on train crews and their performance, leading to safer equipment design and specifications. A state-of-the-art simulator research facility could also examine safety issues related to advanced technologies, such as in-cab displays, communication systems, and other Positive Train Control (PTC) technologies.

The next cycle of work in the high-speed and freight simulator research program will focus on identifying additional simulator research and data needs along those four functional areas, as defined by the industry, and then prioritizing those needs. Once these needs have been identified and prioritized through the development of a long-term strategic simulator research plan, recommendations can then be made for a simulator research facility that will accommodate the changing needs of the industry, in both passenger and freight operations. Specific recommendations for a simulator research facility will then be defined, including simulator system architecture, simulator system requirements, operational requirements, data collection requirements, and other physical requirements. Locomotive simulation research is an important component in FRA's Human Factors Program. This programmatic effort will not only help define the long-term goals of the overall simulator research program, but will also will help ensure overall utility and effectiveness of the program to the industry, as well as enhance the performance of the Human Factors Program. This work is expected to continue through FY 2005.

Technology in High-Speed Rail Operations

Since the potential for highly or fully automated locomotive control systems first appeared in 1989, work in this topic area has been underway. The intent of the research in this area is to develop a better understanding of safety-related implications of various possible automation levels on operator qualifications, training needs, and performance. Preliminary studies have been completed on how human operators respond to varying levels of technical assistance as well as on how they respond to displays showing information about territory further down the track.

Work has concentrated on developing a more refined high-speed locomotive simulator to create more realism in the displays and the operational scenarios under study. Scenarios to be studied include current displays used by locomotive builders and new methods for potential preview displays of the rights-of-way and operational surroundings. How far ahead the operator needs to "see" will be evaluated. Work in subsequent years will address other human factor issues such as maintenance and management of new technologies for operating systems. This project will continue through FY 2004.

Dispatcher Training Evaluation and Selection

A project is underway to provide recommendations to the FRA on how the quality, uniformity and efficiency of dispatcher training can be improved. Recommendations on training practices, training standards and the amount of training required, both for the initial training of new dispatchers and for periodic refresher training, were published in a report in FY 1999. Information concerning training performance objectives, syllabi, and test designs will next be used as the basis for recommendations for more effective dispatcher selection. The project will be completed in FY 2002.

Figure 4.2.1.

Union Pacific Dispatcher, Omaha, Nebraska

Knowledge Display Interfaces

Knowledge Display Interfaces are one of the component elements of Intelligent Railroad Systems described in Chapter 2. In future railroad operations, digital data links and computer displays will be the norms for moving information among locomotive engineers, dispatchers, and traffic managers. Improved ways of displaying information to them to facilitate their comprehension and use of it will be essential if full use of their potentials as well as the potential of the technology is to be realized. This new technology can be expected to increase safety while increasing traffic density and speed if information is shared between decision-makers and operators and acted upon properly. This joint project with Amtrak and the MIT Media Laboratory has two purposes: (1) to evaluate alternative display concepts, and (2) to provide railroads with innovative digital display environments to enable exploration, analysis, and development of strategies to strengthen and coordinate safe decision-making for new higher-speed operations on the Northeast Corridor. Future work will explore implementation of the technology in freight operations in collaboration with an industry partner. This project is projected to continue through FY 2003.

Crew Resource Management

Recent studies by the Federal Aviation Administration (FAA) of airline cockpit crews, as well as other studies of surgical operating room staff and other informal teams, indicate that the interactions among the members of such teams is a major determinant of human errors. Teams of professionals assembled to perform a specific task during a limited period of time (fly a jet between two cities, or remove an appendix from a patient) often commit life-threatening errors because of misunderstood roles, faulty expectations, and lack of adequate communication. Train crews— engineer and conductor/brakeman and the dispatcher—are also informal teams, and may suffer from similar problems. Moreover, as the railroad industry continues to modernize, it can be expected that such informal teams will also include maintenance personnel. The objective of this project is to examine the crew interactions that exist in current railroad operations which effect safety and to develop strategies to enhance safety through more effective "teaming." This project is currently in progress and is expected to continue through FY 2004.

Workload Transition Effects

Rapid transitions between periods of high workload and low workload are typical of current train operations. Such workload transitions are known to adversely affect situational awareness (knowledge of present place, time, and circumstances) and can result in serious operational errors. The purpose of this project is to determine the extent to which rapid workload transitions affect train-handling performance and to develop strategies to ameliorate this effect. This project is planned to commence in FY 2002 and will continue through FY 2005.

Digital Communications

This project will examine the human factors implications of the use of digital communications among locomotive engineers, roadway workers, and dispatchers. Currently, such communications are conducted by voice; and previous work has shown that voice communications are far less efficient and precise than digital communications. Given current advances in technology, a transition from voice to digital communication is a certainty. This transition, however, is also certain to change the tasks (broadly defined) of locomotive engineers. This project will determine the human factors safety implications of this transition. A transition to digital communications without careful observation of the effect on railroad staff could lead to serious safety problems. The project is expected to continue through FY 2003.

Cognitive Task Analyses of Railroad Occupations

Cognitive task analysis (CTA) is a hybrid methodology that combines field observations with structured interviews to build and progressively refine an understanding of the demands of a job and the knowledge and strategies that are used by experienced individuals to respond to those demands. CTA describes the mental planning of tasks, rather than the physical actions that are carried out. CTA allows the identification of the cognitive skills needed to perform a task proficiently, and is primarily valuable for tasks that depend on cognitive aspects of expertise. Many safety critical jobs (e.g., dispatcher, locomotive engineer) in the railroad industry depend on cognitive expertise, and our ability to understand the human factors safety implications of changes in technology (e.g., digital communications, new displays) or operating practices (e.g., teaming of operating personnel) directly depend on the information that CTA provides. This project will provide basic CTAs for safety critical railroad occupations and specific CTAs, as required, to support other projects, such as the Teaming and Digital Communications project. This project is in progress and is expected to continue through FY 2003.

Locomotive Cab Working Conditions

In 1992, Congress enacted Section 10 of the Rail Safety Enforcement and Review Act (Public Law 102-365), which required FRA to assess the extent to which environmental, sanitary and other working conditions in locomotive cabs affect productivity, health and the safe operation of locomotives. Subsequently, the Human Factors Program has provided research support to FRA's Office of Safety and the RSAC on Locomotive Cab Working Conditions in examining the effects of air quality, noise, temperature, vibration and sanitation on locomotive crews. A Notice of Proposed Rulemaking for locomotive cab sanitation has been published, and work continues on other working conditions issues. This project will continue through FY 2005.

HUMAN FACTORS AT GRADE CROSSINGS

The following projects all relate to human factors issues at grade crossings. Other grade crossing RD&D projects are described in Sections 4.7 and 5.3.

Post-Accident Stress in Locomotive Engineers

Police officers, firemen, and rescue workers who are involved in responding to serious accidents involving loss of life often experience Post-Traumatic Stress Disorder (PTSD). Mandatory counseling is often provided for individuals involved in traumas. Discussions with locomotive engineers indicate that during the course of a career most locomotive engineers experience a traumatic grade crossing accident. At present there is no uniform industry approach to PTSD in locomotive engineers, although anecdotal information suggests that safety may be compromised if counseling is not provided. This project will determine if the experience of a traumatic grade crossing accident is debilitating and examine the efficacy of standard counseling techniques. This project is now in progress and should be completed in FY 2002.

Driver Behavior

The driver behavior project will address a variety of issues concerning the behavior of motorists at grade crossings. The Grade Crossing Research Needs Workshop held in 1995 found that it is unknown why motorists and commercial vehicle operators take risks at grade crossing (e.g., driving around gates, directly in front of trains). Such risk-taking may be correlated with:

- Demographic or sociocultural variables.
- Perceived train speed.
- Perceived distance.
- Credibility of, and warning times for, active devices.
- Sight distance and visibility.
- Driver familiarity with the grade crossing.

Motorists' and commercial vehicle operators' perception of risk may be determined by the perceived frequency of trains, and decisions to cross or stop may be critically influenced by perceived costs and benefits associated with each action (including fines for noncompliance). In the absence of clear information concerning the determinants of risky behavior, efforts to change driver behavior may be ineffective. This project will attempt to identify the major variables that cause risky behavior so that a systematic effort to enhance safety can be undertaken. The first component involves the use of driving simulators, especially the NHTSA's National Advanced Driving Simulator, to create highly controlled environments in which the influence of key factors such as warning device characteristics and road geometry on driver behavior can be studied. This project is in progress and is projected for completion in FY 2003.

Accident Causation Analysis

Accident statistics often fail to identify the real causes of accidents because accident reports focus on what happened, and not why it happened. There are two possible approaches to answer the "why" question. First, an in-depth analysis of accidents can reveal whether there are basic system weaknesses that contribute to poor decision-making at grade crossings. "Near accidents" and non-train accidents will be included in this analysis because they are also caused by the same system weaknesses.

Second, a behavioral "post-mortem" of grade crossing accidents can reveal information concerning driver motivation, state-of-mind, stable behavioral patterns, and demographics that may bear on accident causation. Such information is gathered by interviews with friends, the family of the driver, and witnesses in fatal accidents. For non-fatal accidents, drivers and witnesses will be interviewed. There are standard protocols for the conduct of such interviews that have been extensively used in suicide research. The information obtained will help in targeting audiences for safety programs and for tailoring messages to specific groups. This project is in progress and is scheduled for completion in FY 2002.

Driver Education Programs

The Research Needs Workshop identified several high-priority research needs in the area of driver education. These include:

- Target audience identification.
- Current and completed research survey.
- Existing programs survey.
- Sources of funds.
- Program evaluations.
- Operation Lifesaver.
- Driver education.
- Grade crossing safety media.
- Trespassing media.

In general, there is a lack of knowledge in each of these sub-topics that impairs efforts to improve the safety of grade crossings. Defining the target audience for an educational program not only improves the efficiency of the message being delivered, but also allows the message to be optimally structured.

Conducting a survey and documenting current and completed research will help identify innovative efforts, while a survey of existing programs—media, print, video, radio, etc.—will avoid duplication of effort and may identify potential partnerships. A survey of funding sources will identify potential alternative funding sources in the public and private sectors. Program evaluations will identify effective and non-effective approaches and programs to be identified so that limited resources can be more effectively used. This project is in progress and will continue through FY 2003.

Commuter Crossing Safety

Commuter railroad operations occur in the most densely populated areas of the country, and often have highway-railroad grade crossings at approximately one-mile intervals along the track. The crossings see high volumes of both railroad and highway traffic during morning and evening rush hours. Unfortunately, this maximizes the likelihood of incidents occurring and the severity of their consequences. This project will focus on the commuting driver's decision-making at highway-railroad crossings and unique opportunities for advanced protection systems, making use of existing infrastructures such as adjacent traffic control devices and urban highway traffic control centers. This project is scheduled to commence in FY 2001 and end in FY 2004.

Human Factors Evaluation of Intelligent Grade Crossing Systems

The behavior of any operator can be expected to change as technology is changed within the system that he or she controls. With the advent of intelligent transportation systems, technology will soon be available to motorists that will advise the motorist of the location of grade crossings and the status of those grade crossings (e.g., train present or not). The effect that such technology will have on the driving behavior of the motorist with respect to a grade crossing is not known. This project will assess the effect of intelligent systems on driver behavior at the grade crossing to ensure that changes in technology improve, rather than degrade, safety. This project began in FY 2001 and should be completed in FY 2004.

PROGRAM EVALUATION

Program evaluation is the systematic assessment of the merit and/or worth of a program. Program evaluations are undertaken to ascertain strengths and weaknesses and provide direction for improvement. Program evaluations also provide documentation for accountability, evidence to guide decision making, and specific recommendations for increasing the overall feasibility, utility and effectiveness of a program's activities. The process of program evaluation identifies important stakeholders and their questions, defines assessment criteria, obtains and analyzes relevant information, judges the program's merit and/or worth, reports the results, and promotes appropriate and effective use of the findings. Sound program evaluations meet standards of utility, feasibility, propriety, and accuracy.

This multi-year effort will systematically assess the strengths and weaknesses of the Human Factors Program and provide direction for improvement, in a formative manner, to help achieve strategic and organizational goals. The emphasis of the effort will be on Program Evaluation, Program Development and Safety Cost/Benefits Analysis. Specific activities to be included will be: (1) the identification of key factors and resources, both internal and external to the agency, needed for improving the program; (2) the development of education, training and assessment tools, such as handbooks, checklists, and various planning documents to help guide the evaluation process; and (3) the development of internal and external measures of success to help measure the impact of the program evaluation on the Human Factors Program. This project began in FY 2001 and will continue through FY 2005.

TABLE 4.2

PLANNED TIMELINE FOR HUMAN FACTORS

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
Yard and Terminal Safety					
One person Remote Operations					
Ergonomic Issues	●	─	─	─	▶
MOW Safety	●	─	●		
Behavior-based Safety	●	─	─	▶	
Train Operations Safety					
Fatigue Tools	●	─	─	─	▶
Human Reliability Analysis in PTC	●	─	─	─	▶
Engineman Vigilance Monitoring	●	─	●		
Dispatcher Readback/Hearback Training	● ●				
High-Speed Rail Simulator	●	─	●		
Technology in High-Speed Rail Operations	●	─	─	●	
Dipatcher Training Evaluation	● ●				
Knowledge Display Interface	●	─	●		
Crew Resouce Management	●	─	─	●	
Workload Transistion Effects		●	─	─	▶
Digital Communications	●	─	●		
CTA	●	─	●		
Human Factors at Grade Crossings					
Post-Accident Stress in Locomotive Engineers	●	●			
Driver Behavior	●	─	─	●	
Accident Causation Analysis	●	─	●		
Driver Education	●	─	─	●	
Commuter Crossing Safety		●	─	●	
HF Guidelines for HR/ITS		●	─	─	▶
Program Evaluation	●	─	─	─	▶

4.3 Rolling Stock and Components

The Rolling Stock program element places emphasis on the development and improvement of equipment defect detection via wayside and onboard systems. Such detection promotes early defect detection and helps prevent derailments due to equipment failure. It also permits condition-based maintenance of car and locomotive components. This program focuses on a pro-active approach to preventing derailments and equipment failure. This approach will involve risk assessment and mitigation, along with support for safety assurance. This program directly supports the strategic goal: provide analytical and technical support that reduces the number of accidents, deaths, and injuries due to rail equipment defects.

Why a Priority?

The past decade has brought about major changes in the operating environment of today's railroads. Past mergers, spinoffs, and modal shifts have not only provided new opportunities for railroad operators, but also increased the performance demands on them. Higher capacity freight cars with heavier axle loads and higher speeds result in requirements becoming more stringent with regard to railroad equipment and component performance. Particularly, as more high-speed trains come into service, the contribution of each subassembly or component to overall system safety is increasing.

In 2000, 12.5 percent of all train accidents were related to equipment failure. Specifically, out of 2,983 train accidents, 372 were equipment related, a 16 percent increase over 1999 and a 37 percent increase from 1997. Mechanical components must withstand increased loads and stresses while operating at higher speeds. At the same time, the need for increased payloads in freight trains and the greater comfort demanded by passengers (i.e., reduced noise and smoother ride) are increasing the material and energy resources required to build and operate rail equipment. Subsystems must therefore be lighter and smaller, and offer greater energy efficiency while maintaining and improving performance. Equipment is being utilized more often and for extended periods of time. The demands on rail equipment are becoming more severe.

Objectives

The main program objective is to identify, analyze, demonstrate, and disseminate information about equipment defect detection technology that has the potential to improve the safety and efficiency of railroads in the United States. This program represents a proactive approach to preventing equipment and component failures that may potentially result in derailments. A second objective is to provide the analytical and technical basis to develop equipment safety standards, especially with emerging technologies.

Expected Outcomes

The expected outcome of the Rolling Stock program will be to minimize the occurrence of derailments, premature equipment failure, and undesired emergency brake applications. This program is also expected to fulfill the demands for faster, heavier, and longer trains by extending equipment and material life through early defect detection and the development of advanced materials. Equipment and component condition monitoring will improve safety and reliability as well as promote condition-based maintenance as opposed to time or mileage-based maintenance. The resulting database created by such monitoring will also provide historical data to study equipment and component life, behavior, and failure rates. The development of wayside and on-board detection and control will bring fully Automatic

Inspection Stations closer to reality. Research results will be incorporated into equipment safety standards and maintenance practices.

Project Descriptions

ELECTRONICALLY CONTROLLED PNEUMATIC (ECP) BRAKING AND ON-BOARD MONITORING AND CONTROL SYSTEMS

These systems are component elements of Intelligent Railroad Systems described in Chapter 2. They enable improved system performance with better safety and efficiency. This research is undertaken with rail industry cooperation.

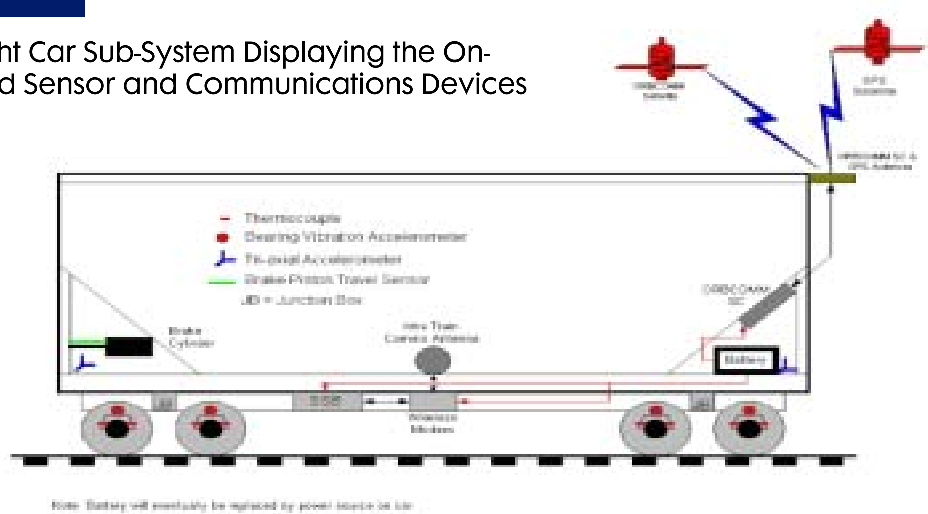
The train line communications systems on locomotives and rail cars utilized in ECP braking can be used to control train functions and monitor the critical systems and their components for early detection of problems such as overheating of wheels, bearings, and brake pads that could be detrimental to safety. On-board monitoring will allow immediate notification to the locomotive engineer and appropriate personnel through the supporting communication network. Safety critical locomotive functions such as locomotive dynamic brake can also be monitored continuously and “alarmed”. The early notification will help reduce the ill effects of sudden equipment failure.

Brake System

New research initiatives are focusing on additional on-board detection and train health monitoring features to be incorporated with ECP brake technology. These features include brake-cylinder and handbrake position sensing, and a running indication of the brake system status. The ECP brake system will provide continuous monitoring of brake system health. This is a new research program that will be expanded during this five-year period. The majority of this work will be conducted in cooperation with the railroad industry. Safety evaluations of advanced braking systems will continue. An advanced handbrake for use on freight railroad cars will be developed and operated in conjunction with the ECP braking system. The new handbrake will be user-friendly and will promote safe and easy braking operations. The

Figure 4.3.1

Freight Car Sub-System Displaying the On-board Sensor and Communications Devices



handbrake will allow remote activation, brake status monitoring, and will require less force for brake release and set. This is an on-going program area. Research on advanced handbrakes is planned to continue through early FY 2005.

Bearing Systems

If a problem such as overheating of bearings is detected early, then steps can be taken to avoid catastrophic failures. The communications protocol and system architecture developed in conjunction with ECP braking systems can be extended to address these control and monitoring activities. Research has been initiated to develop and introduce onboard monitoring technology for monitoring bearing temperature and truck ride quality, entailing the development of transducers and instrumentation that will be compatible with on-board monitoring and communication on ECP braking systems. The freight car system set-up is shown below in Figure 4.3.1. This program area is planned to continue through 2003.

Advanced Train Systems

A revenue service demonstration of smart sensors is planned for FY 2002 and FY 2003. Sensor data will be transmitted via communications satellites to a central database for dissemination with an interval-based system approach. This project will be initiated with a 5- to10-car Advanced Train equipped with ECP brakes and onboard monitoring systems with brake piston travel surveillance, ride quality surveillance, derailment detection, wheel overload conditions, advanced couplers incorporating air and electrical connections, advanced parking brake with remote release, in-train force and impact monitoring, derailment detection, and hot bearing detection. Advanced Train systems could also be operated on main lines as well as in industry switching service and yards. Collectively these features reduce the risk of injury to crews by avoiding high-risk tasks, such as coupling cars and air hoses. Continuous monitoring of onboard conditions will also reduce the potential for derailments. FRA wants to demonstrate this element of Intelligent Railroad Systems to obtain industry acceptance of the concept. For these features to be deployed by the industry, they need to be demonstrated successfully as an overall, integrated system.

As additional companies enter the advanced braking systems arena, brake system safety evaluations and other analysis will be required. Due to increased traffic, car and train weight increases are expected. Thus, research efforts will focus on the development of a Train Dynamic Simulator (TDS). The TDS will be used to evaluate Train Safety and Energy Efficiency of equipment and the railroad as a system. Brake system reliability must also be addressed through further research. Continuous monitoring of locomotive dynamic brake system operability will be addressed further. Train line communications must eventually be implemented safely to enable Intelligent Railroad Systems. Continued support will be provided to the FRA Office of Safely.

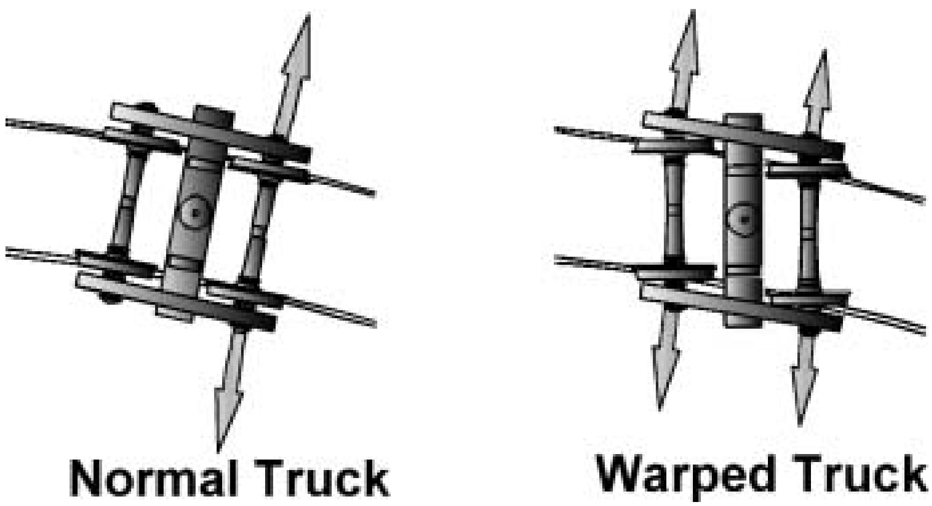
WAYSIDE MONITORING

Derailments due to equipment or component failure must be prevented. To accomplish this goal, development of a new generation of equipment defect detectors, which have the ability to detect defects at their early stage of failure and with a high degree of confidence, is needed. These detection systems must show increased detection ability, control, and improved reliability. Wayside detection research will continue to focus on improvements in this area, as well as focus on the development and establishment of advanced inspection stations. These stations will consist of improved wayside detection systems; possibly using advanced imaging methods. Such systems will monitor wheel wear status, car and suspension dynamics, and improve the reliability, maintainability, and accuracy of hotbox detectors. They will also inspect railcar wheels to identify symptoms of brake defects, hot wheels, and sliding wheel detection. Wayside detection systems are also a component element of Intelligent Railroad Systems as described in Chapter 2.

Research efforts will focus on the development of advanced inspection stations. These stations will be located in high traffic density locations where they will provide the most significant coverage of defects. These stations will involve the inspection of bearing defects, worn wheels, worn trucks, and even truck hunting. The identification of truck signatures is critical because it will provide insight into a truck's condition. Figure 4.3.2 displays a normal truck signature and a warped truck signature. Warped truck signatures increase the potential for derailments. Figure 4.3.3 shows the set-up for the Wayside Inspection test site in Loudon, Tennessee. This work is being done in cooperation with the railroad industry. Such stations will provide more rigorous safety inspections than are possible visually, and demonstrate increased reliability and detection ability. Alternative new technologies will continue to be explored for detecting defective bearings and cracked wheels.

Figure 4.3.2.

Normal Truck Signature vs. Warped Truck Signature



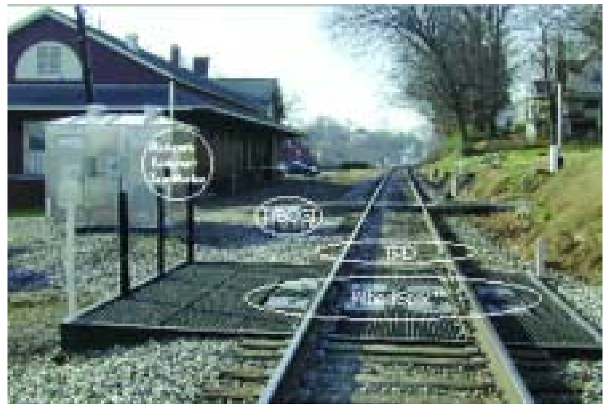
Commuter railroads, in particular, experience overheated wheels because of their frequent stops. Wheel overheating during braking can result in undesirable stresses in wheels as illustrated in Figure 4.3.4. The beneficial effects of quenching during manufacture can be overcome by significant stresses induced due to rapid heating. High-speed thermal imaging ("thermography") needs to be developed to the point that it can be incorporated into advanced wayside inspection stations. Thermal imaging improves reliability, maintainability, and accuracy of hotbox detectors and can also inspect rail car wheels to identify symptoms of brake defects (i.e., sliding wheel detection). Thermal imaging systems scan the entire wheel, bearing, and truck assemblies. They can operate as a stand-alone unit or with the addition of an Automatic Equipment Identification (AEI) reader. Research will continue to determine equipment defect characteristics (i.e., bearing acoustic signatures) in an effort to develop the ability to predict defects and prevent failures before they occur. Research into the advanced imaging of bearings will continue through the end of FY 2003.

Wheel research will continue to focus on nondestructive testing methods and the development of in-service inspection of wheels for limiting wear and related reasons for removal. Efforts will focus on the development of in-situ detection systems to assess the stress state in wheels, as well as detect and define cracks and/or other flaws in the tread. Research to measure wheel wear in place will also be initiated and supported. Wheel research is an on-going activity.

Bearing life with an increased axle load will be evaluated and improved. It may even be necessary to develop and evaluate new and improved bearing materials and designs. Basic research, applied research, and laboratory testing will be conducted. Bearing research will continue through the end of FY 2003.

Figure 4.3.3.

Wayside Inspection Station Test Site at Loudon, Tennessee



MATERIAL IMPROVEMENT AND DESIGN

Continuing research is needed for improvement of materials used in railcar components. For instance, coupler material needs to be more crack tolerant with higher strength, improved fracture toughness, and cleanliness of the cast steels. The demand is for steels that are readily available without pre- or post-heat treatments. Research in the area of improved coupler material and design will be continuing during this five-year period.

For the work proposed, research metallurgists working with casting manufacturers will serve as consultants. The group will analyze present cast steels to determine ways of modifying the material to meet the present and future demands on couplers. Test castings will be poured, and tests on hardness crack growth, and weldability will be run to determine possible material improvements. The new types of cast steel will also be used for other railroad castings.

Fully Automatic Coupler

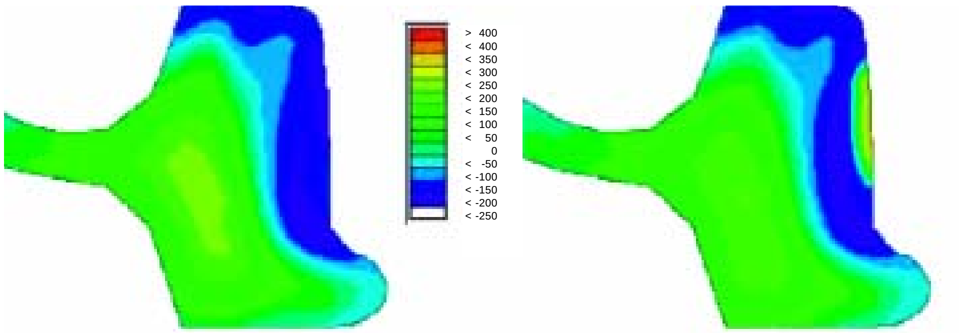
Current freight car couplers have no provision for automatically making the braking air connection or any electrical connections. These couplers have a limited gathering range (misalignment tolerance) and must be manually prepared for coupling, which poses a risk to the operator. Research initiated in FY 1998 under the Small Business Innovative Research (SBIR) program will continue to develop a mechanically compatible knuckle-type coupler that will couple to standard couplers and which when coupled to a like new design coupler will provide for automatic air and electrical connections. Automatic coupler research is planned to continue through the end of FY 2003. Research will continue to look into remote means for mechanical uncoupling and remote operation of angle cocks.

Advanced Cushioning Devices

Both freight and passenger cars are subject to yard impact forces. The longitudinal impacts are controlled with hydraulic cushioning devices which employ hydraulic metering of oil through small orifices; thereby, preventing high coupler loads and acceleration from acting on the car and its lading. However, the travel associated with those devices is detrimental in over-the-road train operation. It results in excessive slack action that affects safe operation. Train action forces may lead to derailments and/or gage spreading. An automatic or remote means to electrically lock-out the orifices prior to trains departing yards—perhaps utilizing the ECP brake train line—will be researched and developed. Research on advanced cushioning devices will continue through early FY 2003.

Figure 4.3.4.

Wheel Profiles Showing Estimates of Thermal Stresses in New and Used Commuter Car Wheels



As manufactured **After simulated service**

Advanced Handbrake

Research was initiated in FY 1998 under the SBIR program to develop an automated handbrake to hold cars stationary on level track or on grade to prevent car runaway as sometimes occurs with present handbrakes. This new handbrake is compatible with the present air brake system and will be compatible with the newly developed ECP brake system. Phase 1 has been completed and Phase II is slated for completion in FY 2002.

TABLE 4.3

PLANNED TIMELINE FOR ROLLING STOCK AND COMPONENTS PROJECTS

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
Outboard Monitoring Systems					
Brake System Status	●———	————	———●		
Bearing Tempertature	●———	————	———●		
Overall System (G-force, detailment detection)	●———	————	————	————	———►
Wayside Monitoring System Demonstrations	●———	————	————	————	———►
Material Improvements & Design					
Fully Automatic Coupler	●———	————	——●		
Advanced Cushioning Devices	●———	————	————	——●	
Advanced Handbrake	●———	————	——●		

4.4 Track and Structures

The Track and Structures Research Program element covers all aspects of the railroad guideway, including embankments, ballast, ties, fasteners, rail, turnouts, bridges, and tunnels. It encompasses track geometry measurement, defect detection, and design and maintenance issues. A significant portion of FRA's Track and Structures Research Program involves a joint effort with three of the AAR's Strategic Research Initiatives: Track Integrity Monitoring, Bridges, and Track Components.

Why a Priority?

Today, one third of all railroad accidents are attributable to track defects. Based on FRA's accident/incident statistics for the five-year period of 1996-2000, an annual average of 943 incidents were attributed to track as a primary cause.

While the track-related accident rate was relatively steady during the 1990's, the reported damage grew significantly, doubling from $55 million in 1993 to $111 million in 2000. As the reported damage figures only include direct property damage, the full cost of these accidents is estimated to be about 2 to 3 times higher.

The operation of longer trains with heavier axle loads and the increased and more concentrated traffic on fewer main routes, are contributing factors to the increased cost of track-related accidents. The anticipated trend is toward even heavier cars with greater axle loads and higher train speeds, thus increasing potential accident severity. In addition, future demand for more passenger and commuter service operating at higher speeds will further tax the capacity of existing routes while also reducing available track maintenance time. Track in these shared passenger and freight corridors will be subjected to more demanding requirements—heavier load carrying capacity, greater durability for freight service, and greater geometric precision for faster passenger service.

Objectives

The primary objective of the FRA's Track and Structures Research Program is to reduce accidents, deaths, injuries, and property damage related to track and other infrastructure failures.

Another objective is to anticipate and address safety issues concerning emerging technologies before their widespread use and to facilitate their safe implementation in the future. These objectives are achieved by providing the technical basis for the development of safety standards and best industry practices for maintenance, inspection, and train operations. The Track and Structures Research Program has been evaluated through a five-step "fault-tree" process, described in Chapter 3, with the objective of developing an explicit rationale for project selection and program development.

The Track and Structures Research Program is directed along three fronts, described in more detail in the remainder of this section. First, is the development and implementation of techniques to more effectively and rapidly locate track defects and to better assess track conditions. Second, is the assessment and shared development of improved track and structure materials and components to withstand higher loads and provide greater durability and safety. And third, is the examination of techniques for improving the performance of the track structure as a whole, to provide a more viable and stable structure under heavier loads and higher speeds.

Inspection Technology and Data Analysis

This research area has the two objectives. One is to improve the efficiency and effectiveness of track, bridge, and roadway inspection. Another is to develop methods for more effectively applying inspection data to improve diagnostic capabilities and track maintenance planning, and to optimize inspection scheduling.

To achieve these objectives, the research will emphasize the development and adaptation of improved sensor and computing technologies, as well as the integration of advancements in wireless communication and location identification technologies, such as the Global Positioning System (GPS). Increased efforts will also be made in the development of sensors for measuring vertical track support and the potential use of Ground Penetrating Radar (GPR) as diagnostic tools in identifying track defects due to subsurface conditions. These are part of the Intelligent Railroad Systems activities described in Chapter 2.

FRA research has produced several generations of instrumented railcars, the latest of which are the T-6, which measures the gauge holding strength of track, and the T-16, which measures track geometry, wheel/rail forces, and ride quality at track speeds reaching up to 150 miles per hour. To quantify track conditions and to determine operational safety, software aboard these cars compares the measurements to the Federal Track Safety Standards, as well as other established or proposed performance guidelines, and provides accurate mapping and description of all identified defects.

Data from these cars also supports the development of track degradation and vehicle/track interaction models, which are part of the Track and Structure Design and Performance, and the Track/Train Interaction research areas. The future integration of inspection techniques with track degradation and vehicle-track interaction models will allow instant update to track maintenance plans, as well as real-time evaluation of operational safety, as inspections are being performed.

Future efforts will monitor the pace of developments in the emerging fields of micro-electro-mechanical systems (MEMS) and nanotechnology, which promise to allow molecular-sized condition sensors to be embedded into track components during manufacturing. As part of a remote health and condition monitoring system, the wireless micro-sensors may transmit a condition alarm to a location or be read by inspection cars passing over the track. Nano-sized sensors embedded in rail or other track components could also measure stress levels, a capability that may greatly improve the buckling safety of continuously welded rail.

Materials and Components Reliability

Some accidents and infrastructure deficiencies relate directly to weaknesses or defects in individual components or materials. This research area focuses on collaboration with industry efforts to improve the design, material composition, and repair of individual components to withstand the increased demands from heavier and more frequent axle loads, and in particular rails, ties, fasteners, and switch components. Other efforts focus on improving the understanding and modeling of defect formation and propagation, and enhancing the ability to predict defect growth rates for timely action before accidents can occur.

The products from this project group will help produce stronger and more durable components and materials, more effective repair and maintenance techniques, and therefore fewer accidents and derailments due to such failures. The knowledge gained will also serve as a rational basis for enhanced FRA safety standards and rules for inspections and mandated remedial actions, as in the safety critical areas of internal rail defects and rail welds, and for guiding improved industry practices for maintenance planning and structural repairs.

Track and Structure Design and Performance

Beyond the component level, other accidents and infrastructure deficiencies result from the deteriorated behavior of the track structure as a whole. In these cases, the problems and needs must be addressed through consideration and understanding of the interaction between track components.

The products from this project group will help produce a more stable track structure along with models to predict track deterioration under a variety of conditions. These new techniques will serve as the basis for performance-based track safety standards.

Expected Outcomes

Expected outcomes are:

- Better understanding of fracture development and growth mechanisms in rail steel under passing loads.
- Improved nondestructive (field) test methods for detecting flaws in rail steel.
- Improved methods for determining when track is at risk of sudden lateral buckling or of pulling apart from rail longitudinal forces induced by seasonal temperature changes or by tractive or braking forces.
- Advanced inspection technologies to detect track hazards (e.g., track bed weakness, wide gage, and faulty geometry) well before accidents can occur, as well as safe load capacity and structural integrity of bridges.
- Incorporation of research results into FRA Track Safety Standards and railroad maintenance practices.

Project Descriptions

INSPECTION TECHNOLOGY AND DATA ANALYSIS

Rail Defect Detection

This effort is aimed at producing better and faster methods for detecting internal rail and joint bar defects and developing automated methods for better and more consistent interpretation of rail defect measurement data. Plans include expansion of a Rail Defect Test Facility (RDTF) at the TTC. The RDTF is a track containing a wide range (in both type and size) of well-documented internal defects. Additional samples will be installed to include rails with both internal and surface defects as well as other examples of defects, or defect combinations, which have proven difficult to reliably detect. The RDTF will be used to accurately measure the performance of existing detection methods, and then, to diagnose detection deficiencies. From these evaluations, improvements in detection methods and in interpretation of detector measurement data can then be proposed and developed. Improved defect management and repair practices can also be formulated. This work will continue throughout the next five-year period.

Alternative Techniques for the Detection of Broken Rail or Track Hazards

This project will assess the application of new technologies other than those normally used for the detection of broken rail. Special emphasis will be placed upon the feasibility of a train-mounted device for detection of broken rail or other hazards ahead of a moving train. Currently, track circuits for signaling also provide for the detection of broken rail. However, about half of the railroad mileage does not have signal circuits and is otherwise not equipped with a broken rail detection system. In addition, signal circuits are not fully reliable in detecting broken rails. Even where signal circuits are present and a rail breaks without the presence of a train, signals will not always show "Stop" if a rail breaks over a tie plate. Initial efforts will focus on broken rail detection, followed by track hazard detection in general.

Longitudinal Rail Stress Measurement

The ability to measure internal rail stresses is essential for accurately predicting track buckling potential and for prescribing the most effective remedial action to prevent buckling. It is also important for controlling rail pull-apart. This capability has long been desired in the railroad engineering world and the FRA will continue pursuit of this objective. To date, track-mounted methods have shown some success, but what is needed is a method to make these measurements continuously along the track at moderate-to-high speed. A prototype for making localized measurements is planned for FY 2003, with field-testing planned for FY 2004.

Track Gage Widening and Strength Measurements

One of the major causes of derailments is widening of the track gage due to weakened ties and/or fasteners. The resulting inability of track to hold gage under load often causes the wheels of a passing train to drop between the rails. In response to this frequent mode of derailment, the FRA developed the T-6 inspection car, which is equipped with the Gage Restraint Measurement System (GRMS), to measure track gage and its holding strength continuously along the track. The T-6 GRMS car has demonstrated consistent ability to detect weak track locations due to unsatisfactory tie and/or fastener conditions. The successful development and deployment of this inspection technology over the past few years culminated in its full use and acceptance by the industry as well as its recent incorporation into FRA's Track Safety Standards as an alternate performance-based standard.

FRA will continue its GRMS testing program for the mutual benefit of FRA's R&D and safety programs and the cooperating railroads. Current plans are in effect for upgrading the aging T-6 to provide for a self-propelled platform and for the modernization of data collection, location identification, and communication systems. The GRMS program will also continue to support FRA Office of Safety in the evaluation of waiver requests from the railroads, and in the implementation of the recently enacted safety standards. Data collected from these activities will also provide critical input to the parallel development of the Track Degradation Model and for determining optimum inspection frequencies.

Current gage restraint measuring capabilities, developed through FRA research, include the GRMS vehicle which is suitable for measuring up to 200 miles per day on a production basis, and a simple manual device, the Track Loading Fixture, which is suitable for measuring gage strength at selected spots. While this type of production testing is well suited for major railroad tracks, it is not as cost effective or practical when testing on short line railroads, through yards and sidings, and on branch lines of major systems. The feasibility of a more easily deployable and lighter system for gage strength testing that can meet the need for smaller scale testing in a cost-effective manner will be investigated.

Vertical Track Support Measurement

Vertical deflection measurement can enhance the maintenance of safe track structures by locating areas of inadequate or non-uniform vertical support. Such conditions, which are generally not detectable through visual inspection of track, may be due to improper maintenance of transition points, such as bridge approaches, poor drainage, or poor soil load-bearing capacity under the track structure.

Currently, few systems are able to measure vertical track deflection under load using wayside, static techniques. These systems are typically installed at a specific location along the track right-of-way, and some may require that instrumentation be imbedded in the base layer beneath the track. While generally accurate, the existing systems are costly to install and maintain, and can only provide "spot" measurements of vertical track stiffness, and thus are of limited usefulness in wide-area inspections. Therefore, the FRA has determined that a more cost-effective vehicle-bound measurement system that can make continuous stiffness measurements under load will provide a much needed enhancement to track safety inspections.

A feasibility study commissioned by FRA has identified two potential approaches for obtaining this vertical track stiffness measurement from a moving vehicle. One approach will exploit the relative motion between unloaded and loaded wheels using accelerometers, while the other will attempt a direct measurement of rail deformation using laser transducers. Research currently underway in collaboration with Amtrak will test and evaluate the suitability of both techniques. If further feasibility is concluded, a prototype system will be developed and further tested on the FRA T-16 research car.

Automated Inspection of Roadbed

Track subsurface layers (ballast, sub-ballast, and subgrade) provide the required support to the track structure. Poor subsurface conditions result in poor track performance as well as excessive and uneven track degradation. Uneven degradation results in costly maintenance and adversely affects track safety.

Since ballast, sub-ballast, and subgrade layers are beneath the track structure, they are difficult to properly inspect with purely visual methods. Currently, there is no practical method for rapid subsurface evaluation. However, emerging technologies, such as ground penetrating radar and sonic or vibratory signals, offer promise for developing both improved and automated roadbed inspection capabilities. In collaboration with experts from industry and academia, these technologies will continue to be investigated with further development of the most promising technologies.

Non-Destructive Evaluation (NDE) of Bridges.

As freight car weights increase and bridges age, the need for effective, rapid bridge inspection and strength evaluation methods increases as well. The FRA will work jointly with the FHWA and the AAR to investigate NDE technologies that may be applicable in automated bridge safety monitoring. The intent is to pursue techniques that show a high potential for successful adaptation and deployment. This will be a continuing activity.

Automated Analysis and Interpretation of Inspection Data

A key element in raising inspection speeds and in improving inspection effectiveness is taking better advantage of the large amount of data produced by modern inspection techniques. Efforts in this important but often neglected area of research will focus on innovative and improved ways for real-time viewing and display of inspection results and the production of relevant and meaningful inspection reports and summaries. Automated analysis and interpretation will permit diagnosis of many conditions at the time inspections are being made, taking into consideration more variables than can be practically incorporated into the process by slower, manual methods. A variety of track and structure inspections will be benefit from this research.

Probability-Based Inspection Criteria

Many standards for quality control and safety assurance throughout the industrial world are now based on probability theory, data, and estimates. In this group of projects, the sciences of probability and engineering reliability will be applied to develop criteria for inspection scheduling and for characterizing track condition during an inspection. A probability-based inspection schedule would emphasize sections of track with a higher likelihood of having defects. It would also consider the likelihood of missing defects in areas and under conditions where inspection is more difficult. With a probability-based approach, the severity of a defect is related to a combination of its likelihood of leading to a failure before the next scheduled and the likely consequences if a failure would occur. This approach will be developed to cover a wide range of track and track/train interaction inspection.

MATERIALS AND COMPONENTS RELIABILITY

Rail Integrity

Rail integrity research is aimed at extending the life of rail until it must be removed due to either fatigue failure or wear beyond allowable limits. This research includes the study of rail steel properties; defect formation and growth rates; the effects of residual, thermal, and train-applied stresses; surface wearing characteristics; and maintenance grinding and lubrication practices.

FRA will continue to support the development of rail steels that are more resistant to defect formation. Studies in this area will focus on factors that control rail service life and performance, including growth of fatigue cracks, influence of metallurgy, and the influence of rolling loads on residual stress formation and its relationship to fatigue defect initiation and growth. Future work in this area will concentrate on appropriate actions to be taken to: (1) remedy detected defects, (2) improve the metallurgy through processing and post processing of rail steels, (3) assess the safety implications of various rail grinding and lubrication procedures, (4) investigate optimum rail section design to extend rail life while reducing the risk of accidents. Defect growth studies will continue in FY 2001-2003, with validation of growth prediction models planned for FY 2003-2005.

While not viewed as a major cause of accidents, worn rail is suspected of being a contributing factor in some cases. The exact nature of its contribution, though, is not well understood. The wear pattern on the rail may be as important as the amount of wear on both the top and gage side of the rail head. Investigation of the effects of worn rail is planned beginning in FY 2002 to provide a better understanding of what problems worn rail may create.

Rail Welding

Despite recent improvements in the process, welds made in the field to join sections of rail or to make repairs still experience high rates of failure. Studies to date of the effects of heavier cars on track indicate that weld failure rates may increase further without better methods to achieve a higher and more consistent field weld quality. This project will support the development of improved materials and processes to produce welds that are less susceptible to defect formation. This will be a continuing activity.

Turnouts and Track Crossings

Turnouts and track crossings are often categorized as special trackwork, as they include a variety of hardware, fastenings, and general construction that is different from typical track structure. Turnouts and track crossings are subjected to especially high lateral forces and large vertical impacts, and therefore, higher wear and failure rates. The beating they receive has been increasing as heavier freight cars enter service in greater numbers. As axle loads increased, special trackwork components have been deteriorating at an accelerated rate and have become more subject to rapid failure. For the 5-year period from 1996 through 2000, turnouts and track crossings were responsible for an average of about 200 accidents and 2 injuries each year. The average annual reported damage was $8.7 million. This represents about 20 percent of all track-related accidents and 9 percent of all track-caused accident damage.

This project, in collaboration with the railroad industry, focuses on improving the geometric and material design of these components to better withstand the higher forces and impacts of heavy axle loads as well as reduce wear and deterioration rates. Promising alternatives to conventional designs will be tested on the FAST track at TTC to determine their performance and durability. Results from these tests will help to develop improved designs that will withstand expected future load levels. This will be a continuing activity.

Ties and Fastenings

Railroad ties are typically made of wood. In recent years, a substantial number of concrete ties and a small number of steel ties have been installed on U.S. railroads. Now, ties made of recycled plastic of a variety of designs, glass fiber reinforced wood, and reconstituted wood dust are being produced, together with a variety of rail fasteners, from spikes to special design clip type fasteners. In particular, plastic ties have already penetrated the market, with thousands being installed at various transit properties. FRA will continue to cooperate with the railroad industry in this area to test and monitor the performance of these new components and materials and will participate in industry-sponsored workshops and seminars to facilitate the exchange of information between potential users, manufacturers, and the engineering community, to build a consensus for minimum performance requirements for their implementation and safety evaluation.

Ballast and Subgrade

In addition to the innovative inspection techniques for subsurface evaluations, which were outlined in the previous section, FRA will continue to research the causes for ballast and subgrade degradation and failure, and in particular with respect to fouling and drainage. Studies regarding ballast particle size and shape (i.e., number of faces, edges, and corners) also appear to offer promising results.

Composite Materials for Railroad Infrastructure

Composite materials have been increasingly recognized as viable construction materials for a wide range of structures with distinct advantages in some special applications. These advantages include: light weight, high strength, wear resistance, corrosion resistance, dimensional stability, and design flexibility particularly in forming complex shapes. Ultimately, the potential for their increased use in railroad infrastructure applications is their competitive advantage on a life-cycle-cost basis. Ongoing studies at West Virginia University and the University of Missouri at Rolla under the FRA university research grants program will focus on investigating load transfer characteristics between the old and new materials as well as the reliability of connections and durability of the new materials. This effort is planned to run through FY 2002. Future efforts will include the investigation of the potential use of Smart Tagged Composites in structural elements. In these applications, it is envisioned that the tags can be interrogated or monitored using conventional non-destructive techniques with respect to predefined condition or response to service loading.

TRACK AND STRUCTURE DESIGN AND PERFORMANCE

Track Performance under Heavy Axle Loads

This project has three focus areas. The first provides support for operation of the joint FRA/AAR-funded Facility for Accelerated Service Testing (FAST) at TTC. It includes the operation of the heavy axle load train around the FAST track that enables the performance of subgrade, ballast, ties, fastenings, rail, and track stability to be evaluated in a controlled laboratory-type environment. The second focus area is the evaluation of heavy axle load effects in actual railroad revenue service. This will allow a wider range of variables to be evaluated than can be achieved at FAST. The third focus is on branch lines and short lines, where track and bridge construction is often different from that found on main line railroads. This effort is being carried out cooperatively with the American Short Line and Regional Railroad Association. The heavy axle load experiments have significant safety implications and will provide the technical support on which to base improvements in safety regulations. This will be a continuing activity.

Track Degradation Model

A computer model for predicting the character and rate of track degradation has been long desired in the railroad industry and research community. Such a model would provide many important benefits, including showing the effect of track defects which occur in combination. Presently, the track safety standards are, to a great extent, based on individual defects because the ability to clearly define combined effects has not existed. This effort would focus on combining elements of the complete track degradation model, which have been developed over the years but have not yet been integrated into a comprehensive model that accounts for the proper interaction among them. Factors leading to track surface deterioration will be properly quantified, both at the component and system levels, as they act in combination. The result of this project will be a complete track degradation model that will be used as a basis for a more rational maintenance planning and a more optimum safety inspection scheduling. The model will also support the development of performance-based track safety standards. An initial model is planned for 2003, with further refinements to follow.

Upgrading Track for High-Speed Operation

FRA's report of September 1997, *High-Speed Ground Transportation for America*, indicated that the most practical and economically feasible way of providing high-speed rail service to U.S. corridors is to upgrade existing routes and provide for their joint use with freight trains. Although generally less expensive than all-new construction, upgrading tracks for joint high-speed passenger train and freight use presents its own complications and challenges. The main complication is providing a track structure that will practically accommodate two uses with such differing requirements—lightweight passenger trains at high speeds and heavily loaded freight trains at slower speeds.

This project focuses on two tasks: roadbed rehabilitation, and track structure design. One issue in a successful upgrading of track is the extent of roadbed rehabilitation required and the cost-effective methods for accomplishing it. Another is building a track structure on the roadbed that will provide the precision surface and alignment required for high speed service, while at the same time, withstand the heavier loads of freight service without experiencing rapid deterioration or requiring constant maintenance. Results from this project will lead to the development of: (1) general criteria for determining the extent of required roadbed rehabilitation; (2) methods for assessing roadbed rehabilitation requirements at each site; (3) design criteria for track which will accommodate high speed while withstanding heavy loads; and (4) methods to evaluate track components or designs specifically intended for high speed track upgrade. A study of requirements is taking place FY 2001 through 2003, with criteria development in FY 2004-2005.

Alternative Track Designs

The demands on conventional track structure have greatly increased, as heavier freight car weights are requiring greater load-carrying capability while higher speed commuter and passenger trains are requiring tighter tolerances for surface geometry and alignment. This project will focus on the development of track structure designs that can better accommodate heavier loads while retaining the precision surface and alignment required for higher speeds. Examples of alternative track designs include slab track and embedded rail track, which do not incorporate ties or conventional ballast sections. Technology scanning is now taking place, with field tests of promising concepts occurring in FY 2003 through FY 2005.

Track Panel Shift Risk

Track panel shift is a localized lateral movement of the track. While track buckling occurs suddenly due to large compressive stress in the rails, track panel shift occurs gradually and steadily in one direction, due mainly to lateral loads from passing trains. High-speed rail operations are more sensitive to track panel shift because of the strict track alignment limits for higher speeds. This project aims at a better understanding of the track panel shift phenomenon, why a particular track segment may tend to shift alignment while adjacent sections remain in place, and how panel shift might be prevented or controlled. Initial studies and panel shift prediction models will be followed by field tests in FY 2002 through FY 2004.

Track Buckling Prevention

Buckled track initiates from the buildup of large compressive stresses in the rail, often from hot sun and high air temperatures, and is sometimes triggered by added forces from passing or approaching trains. Track maintenance work that disturbs or temporarily weakens the ballast section accentuates the problem.

This project is aimed at two objectives: improving the ability to determine track buckling risk and improving the ability to control track buckling risk factors and thus reduce risk levels. The project includes three tasks. First is the development of a computer program to help determine the conditions under which track buckling is likely to occur and the magnitude of track buckling risk. Railroads can use this program to improve their track buckling prevention plans. Second is the development of techniques to measure rail stress and lateral track resistance. These will provide inspection tools to help assess track buckling risk and to obtain more accurate information to feed the buckling program. Third is the development of procedures for minimizing track-buckling risk when performing track maintenance and for quickly restoring lateral track strength. Validation of current computer models is now underway, with incorporation of improved rail stress and ballast resistance measures occurring in FY 2003 and 2004.

Track Transition Safety

Deteriorating track condition at locations where track construction changes is a chronic problem. These transition zones occur at bridge ends, road crossings, tunnels, turnouts, and track crossings. Abnormal deterioration at these locations is consistently recorded and observed in all FRA's automated measurements of track parameters such as geometry, lateral track strength, ride quality, and wheel/rail forces. Transportation Research Board (TRB) Committee A2M01 has identified this problem as a high priority and an urgently needed research topic. The railroad industry figures indicate that from 8 to 20 twenty times more maintenance is required at the transition between a bridge and standard ballasted track as compared to standard track away from these transitions.

Current research in automated track subsurface condition assessment and vertical strength measurement is expected to complement this research effort to mitigate the transition problem. Techniques for using these measurements in a comprehensive system design approach have the potential to enhance track safety by limiting one major source of track geometry exceptions. Methods to limit the settlement at bridge abutments will be investigated, and track stiffness matching procedures will be developed for increasing the uniformity of track support across these transition zones. This will be a continuing effort.

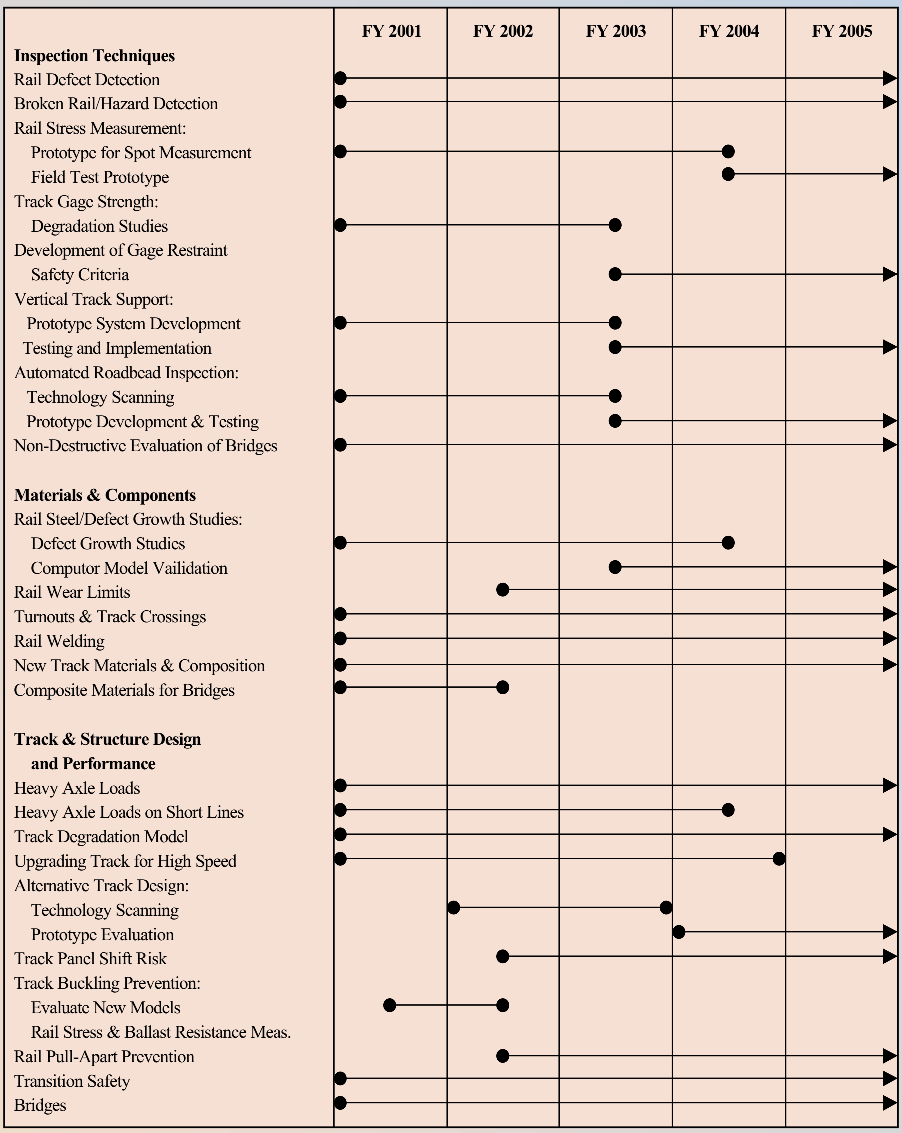
Bridges

As freight car weights increase, bridge safety is becoming an increasingly important issue for the Nation's railroads. The FRA recently initiated the first phase of a cooperative research project with the AAR that builds on the results of previous AAR/National Science Foundation joint research. The objectives of this cooperative research project are to develop fatigue life and strengthening methods for railroad bridges, design criteria for safe operation of modern freight equipment, and non-destructive techniques for reliable prediction and detection of incipient structural failure. This phase-one effort will serve as the foundation for possible further applications to railroad bridge safety inspection.

A second effort is undertaken in collaboration with the FHWA and the West Virginia Department of Transportation to investigate the application of composite materials in bridge rehabilitation. An FRA R&D grant to the West Virginia University at Morgantown explores applications to the repair of timber railroad bridges, and another complementary grant to the University of Missouri at Rolla explores the applicability of composites in the rehabilitation of railroad steel bridges. Research will also continue to focus on technology developments in sensors, communications, data processing, pattern recognition algorithms, and materials, particularly composites, and their application to railroad bridge inspection and repair.

TABLE 4.4

PLANNED TIMELINE FOR TRACK AND STRUCTURE PROJECTS



4.5 Track/Train Interaction

The Track/Train Interaction Program focuses on all aspects of vehicle/track interaction safety. A number of train derailments or accidents cannot be attributed to defects in either track or train alone. Rather, they result from the adverse dynamic interaction between the two or the existence of unsafe conditions at the wheel-to-rail interface, (i.e., improper lubrication or contact geometry). Such interaction includes the instantaneous transfer of dynamic forces from vehicle to track and extends to cover cumulative effects on track degradation such as wheel and rail wear, surface fatigue of the railhead, and deterioration of track geometry. Safety-related issues which will benefit from this research include the development of optimum wheel/rail profile maintenance and monitoring methods, the improved understanding of the impact of high-speed passenger service on existing tracks, and the influence of combined track geometry anomalies on vehicle safety, the establishment of limits of vehicle motion for minimum ride safety and quality, the refinement of performance-based vehicle-track interaction standards, and the development of guidelines for optimum inspection and maintenance practices to enhance system safety and durability. Research in this area therefore presents an integral approach to understanding the behavior of the vehicle/track system in order to identify the safety implications arising from the dynamic interaction between track and train.

Elements of the FRA Track/Train Interaction Research Program will continue to involve joint efforts with two of the AAR's Strategic Research Initiatives: Wheel/Rail Asset Life Extension, and Vehicle/Track Performance. FRA's program however will continue its increased emphasis on problems related to high-speed passenger and commuter services in direct collaboration with Amtrak, regional commuter rail authorities, APTA, and the freight railroads.

Why a Priority?

Certain train derailments continue to occur without proper explanations as to their cause. Since most derailments result in significant damage to track or train or both, it is difficult to single out incidents caused by excessive vehicle dynamics or those caused by unsafe contact conditions. But, based on the most recent safety statistics published by FRA, more than 10 per cent of the reported derailments were due to excessive vehicle dynamics and geometry or wheel/rail profile irregularities. Moreover, in recent years, the railroad industry has seen a proliferation of new and unconventional types of rolling stock, such as double-stack container cars and RoadRailers, which interact differently with track than do more conventional cars. Other recent changes include higher operating speeds for freight and passenger services, the wide use of lubricants on rail to reduce wear and rolling resistance, and the application of rail grinding to remove cracks and other surface defects from rail, or to alter the nature of contact between wheel and rail. FRA needs to continue research in this area to keep pace with the impact of such changes on rail safety, to improve its understanding of previously unexplained and new types of derailments or failures, and to revise its safety standards to accommodate such industry trends.

Objectives

The overall objective of this research is to improve the understanding of the safety aspects of track/train interaction in light of the continual and evolving changes in industry track maintenance practices and in the running equipment. The research conducted will develop analytical tools, instrumentation, and test data that can accurately describe the interaction between the rolling stock and the supporting track structure. Information and data established by this research program will be disseminated to the FRA Office of Safety and the railroad and supply industry to aid in the safety assurance of railroad operations and to promote safety practices within the industry. More specific objectives include:

- Reduce rail accidents due to poor vehicle/track interaction.
- Improve understanding of safety-critical limits of wheel/rail dynamic behavior.
- Establish safety criteria for the prevention of flange climb and other derailments.
- Develop safety guidelines for wheel/rail profiles and contact conditions.
- Develop limits for minimum passenger ride safety and quality to minimize injuries.
- Establish the impact on safety resulting from the use of new lubricants and lubrication practices.

Expected Outcomes

Typical outcomes to be expected are as follows:

- Improved analytical and experimental methods for assessing derailment risk due to anomalous interactions of track geometry and railcar suspension systems.
- Performance-based standards and guidelines for vehicle/track interaction and ride safety and quality.
- Safety standards and guidelines for transverse wheel and rail profiles.
- Improved guidelines for rail grinding and lubrication for optimum wheel-rail contact and truck steering in heavy load and high-speed situations.
- A comprehensive computer program for modeling and simulating railway vehicle/track systems, with an emphasis on the dynamic performance of both vehicle and track and their interactions through the wheel/rail interface.
- Improved modeling of in-train dynamics and the development of better guidelines for train make-up.

Program Descriptions

DERAILMENT MECHANISMS & PREVENTION

Influence of Track Geometry

Heavy freight trains can cause degradation of track geometry in several dimensional parameters. This degradation can be a function not only of axle loading and speed, but also of subgrade characteristics together with the tracking behavior of the trucks that support the railroad car. Research efforts are now underway to address this problem and to assess the influence of the various elements—track, load, vehicle—to separate their individual contributions, and to assess where improvement in component—track or vehicle—performance will decrease the rate of track degradation under service loads. This study will objectively determine the reduction of track quality over time under service, to aid in the development of recommended inspection and maintenance intervals, and to predict the onset of unsafe track conditions if adequate maintenance is not applied.

Future activities will broaden the base of knowledge regarding the limiting conditions of track geometry parameters that will allow safe passage of trains or may contribute to the risk of derailment. Issues such as vehicle response to multiple repeated or combined track defects will be rationally examined through analysis and testing. The objective is to develop guidelines for track geometry limits based on vehicle performance. Progress in this research program provides support for the continual effort to improve FRA's track geometry standards and to guide FRA's inspection policy and frequency.

Other activities will focus on developing rational methods for identifying differing track qualities within the same track class. Current FRA standards identify various classes of track, and subsequently allowable speeds, based on established and fixed limits on track geometry anomalies. For example, tracks may be grouped in the same class regardless of the number of near defects per mile associated with each. Future activities will attempt to further qualify such differences in track quality based on the frequency of anomalies or near anomalies, the prevalence of certain combination of anomalies, the rate of degradation, and the severity of carbody/truck vibrations and wheel/rail forces that may result from the interaction of designated railroad cars with such tracks.

Wheel/Rail Interaction and Lubrication

This is a comprehensive effort that addresses critical behavior of the wheel-rail interface as it controls the safe behavior of the wheel flange on both curved and tangent track. Wheel/rail contact safety is addressed from a systems viewpoint; and specific areas of investigation will include the effects of rail lubrication and railhead grinding upon safe performance of this interface, and in particular their effects on hunting and curving behaviors. This work is planned to continue until FY 2005. Other activities include a cooperative research program between the FRA and APTA to develop wheel and rail profile standards for commuter and passenger rail operations, and a cooperative research program between the FRA and AAR to assess the impact on hollow tread worn wheels on derailment safety. The latter, in coordination with one of AAR's Strategic Research Initiatives, will provide for an increased awareness of the causes of wheel profile related derailments and ultimately the identification of ways to reduce their risk and occurrence. Another cooperative agreement between the FRA and the National Research Council of Canada will focus on wheel/rail friction management and profile optimization for commuter and passenger rail services. This work is planned to continue until FY 2005.

Forces in Special Trackwork

Research in this area is intended to examine methods and techniques for reducing wheel/rail forces that are generated when traversing special trackwork. Emphasis is planned on field retrofits and maintenance practices which can reduce the generally high interaction forces that typically result in poor ride quality and high maintenance costs, and in some cases, accidents and derailments. This research is ongoing.

VEHICLE-TRACK PERFORMANCE

Vehicle/Track Interaction Safety Criteria

The FRA has recently issued new vehicle/track interaction safety criteria for the high-speed track classes 6 to 9, which allow operational speeds ranging from 80 to 200 miles per hour. The criteria have been already successfully applied in the qualification of a number of new types of passenger equipment, such as Amtrak's Acela Express train sets and Kawasaki by-level commuter coaches, for higher speed operations in the Northeast Corridor. This success, however, still pointed to a number of areas that require further research. Examples include the determination of whether additional safety limits are needed to control short wavelength track warp, and the possibility of tighter limits on the allowable net lateral axle load ratio under heavier axle loads to better control track panel shift. FRA R&D will continue its support to the Office of Safety in these safety critical areas to develop an objective assessment of the new standards and to provide rational basis for future refinements and/or revisions. This research effort in safety support is expected to continue throughout the next five years as the new safety criteria are implemented in light of near-term upgrades to higher speed services on the Northeast Corridor and elsewhere in the country.

In a new project that will start in FY 2002, FRA will begin to analyze and establish the requirements for passenger ride safety and quality under high-speed train operations. High-speed rail travel induces vertical as well as horizontal vibrations into the passenger carrying vehicles. These vibrations, which can excite a wide frequency range, are transmitted at the floor level to the traveling passengers. The impact of short duration transient vibrations on occupant safety is little understood. Analysis, and possibly limited laboratory testing, may be required to determine the limits of vertical and horizontal vibrations that may impact passenger's safety. FRA's track safety standards for high-speed rail operations intend to limit the dynamic motion of passenger carrying vehicles and additional research is needed to better define the safe and acceptable limits for such motion.

In a complimentary activity, the FRA R&D in collaboration with the Office of Safety, Amtrak, the freight railroads, and various State DOT's and commuter authorities, will continue the deployment of its latest track inspection research car, the T-16, on designated high-speed rail corridors and other rail passenger routes around the country. These tests will provide FRA with simultaneous measurements of track geometry, wheel/rail forces, and ride quality for safety assessment of current and proposed rail operations. Data from these tests will also provide input for a variety of modeling and analytical activities as described in the above sections.

Vehicle/Track Interaction under Heavy Axle Loads

This research area focuses on the influence of axle load increases on derailment tendencies and other aspects of vehicle/track interaction that are not addressed by consideration of structural strength alone. Recent research by the industry provided the preliminary conclusion that heavier axle loads do not necessarily produce higher lateral to vertical load ratios, parameters which are central to many derailment scenarios including wheel climb. However, recent FRA-funded studies indicated that heavier axle loads could increase the risk of gage widening derailments. Other findings point to the increase in wheel/rail contact stresses and dynamic forces due to the accelerated surface degradation. Continued research in this area will provide FRA with an enhanced understanding of the significance of heavier axle loads to these critical system performance issues and their full impact on derailment and safety. This ongoing research is planned to continue until FY 2003.

Modeling and Simulation of Vehicle/Track Interaction

In support of many of the activities in this area, the development of a comprehensive vehicle-track model and a wheel/rail interaction model will be necessary for the success of several research and regulatory efforts undertaken by the FRA as a whole. Such an integrated system model can provide, for example, much needed support to: (1) the evaluation of high-speed rail operation on existing track; (2) the refinement of FRA's track geometry standards; (3) accident investigations; and (4) additional performance-based rulemaking for safe train operation. The effort will be devoted to the development of a detailed model of the track structure to be interfaced with an equally detailed vehicle model. Additional efforts will focus on the development of analytical models for predicting the overall surface degradation, wear, and fatigue of the various track components as post-processors to the system model. This research is planned to continue throughout the next five-year period.

TABLE 4.5

PLANNED TIMELINE FOR TRACK/TRAIN INTERACTION PROJECTS

	FY2001	FY 2002	FY 2003	FY 2004	FY 2005
Derailment Mechanisms & Prevention					
Influence of Track Geometry:					
Track Degradation Rate	●———	———	———	———	———▶
Combined Track Geometry Defects	●———	———	———	———	———▶
Track Quality Within Class Of Service		●———	———	———	———▶
Real-Time Vehicle Performance	●———	———	———	———	———▶
Wheel/Rail Interaction & Lubrication:					
Wheel/Rail Interface	●———	———	———	———	———▶
Wheel/Rail Performance Criteria For Commuter Railroads	●———	———	———	———●	
Effect of Hollow Wheels on Derailment Safety	●———	———	———●		
Optimum Wheel/Rail Performance and			●———	———	———▶
Wheel/Rail Friction Management	●———	———	———	———	———▶
Forces in Special Trackwork	●———	———	———	———	———▶
Vehicle/Track Performance					
VTI Safety Criteria:					
HSR Ride Safety		●———	———	———	———▶
Track Panel Shift	●———	———	———	———	———▶
Geometry/Ride Quality Assessment of Current and Proposed Rail Ops.	●———	———	———	———	———▶
VTI Under Heavy Axle Loads	●———	———	———	———●	
Modeling & Simulation of VTI					
Effect of Short Warp Definition on Vehicle Safety	●———	———	———	———●	
Comprehensive Vehicle/Track Model Development	●———	———	———	———	———▶
Vehicle/Track Model Validation	●———	———	———	———	———▶

4.6 Train Control

Virtually all train collisions and elements of over speed accidents occurring today are the result of human error—failure to observe or obey wayside signals, or procedural failures by dispatchers, train crews, or maintenance personnel. Positive train control (PTC) systems using digital data communications, automated means of determining train location, and computer control suitable to provide oversight to the human operators of the railroad system, are becoming available at lower costs than traditional signaling systems. This program element is targeted at maintaining a base of technical expertise regarding the application of these sophisticated PTC technologies in order to provide expert advice and consultation to the FRA Office of Safety and to railroads; and to aid in the development and deployment of PTC systems by providing an affordable, uniform, accurate, continuous, reliable, secure, real-time location determination system throughout the United States.

Why a Priority?

The FRA's 1994 report to Congress, entitled *Railroad Communications and Train Control,* noted that approximately 20 major accidents per year were result from failures of existing train control methods and procedures. Over the prior 10 years, these accidents resulted in 80 fatalities and more than $500 million in accident costs. More recently, the Railroad Safety Advisory Committee submitted its report, entitled *Implementation of Positive Train Control Systems,* to the Federal Railroad Administrator in September 1999. The report indicated that the railroad safety record had improved and that such accidents were now resulting in an annual average of seven fatalities, 55 injuries, and $20.6 million in property damage. The report also notes that "the implementation of other pending rule changes and industry actions could play a role in further reducing these numbers. At the same time, traffic and system density are expected to continue to grow, and the extent to which these factors interact has not been clearly resolved." The NTSB continues to place PTC on its "Most Wanted List" of transportation improvements as it has for the last 13 years, and PTC is listed as a component of the "National Intelligent Transportation Infrastructure" initiative in NSTC's *National Transportation Technology Plan.*

PTC is one of the major component elements of Intelligent Railroad Systems described in Chapter 2 of this Plan. The technologies that comprise PTC are the same as those used in air traffic control, maritime vessel tracking systems, and Intelligent Transportation Systems for highways and transit. In addition to providing a greater level of safety and security, PTC systems are also expected to facilitate the ability of railroads to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and greater track capacity. This is important at a time of growing freight and passenger traffic and increasing congestion.

Objectives

This program element is structured to ensure that an adequate base of technical expertise is maintained to support regulatory development enabling advanced train control systems; and to provide guidance in qualifying new and complex operational, communications, software and hardware revisions. The deployment of advanced technology for train control systems presents the railroad industry with opportunities to advance safety while increasing operational efficiencies. Key aspects of advanced train control systems are safety assurance of the complete system, railroad asset tracking ability along with tactical and strategic planners, and communication strategies. Objectives of this program will be:

- To apply the state of the art of safety review and assurance for safety-critical systems within the FRA's regulatory environment.
- To deploy the Nationwide Differential Global Positioning System (NDGPS) as a nationwide, uniform, and continuous positioning system, suitable for train control.
- To advance the state-of-the-art in tactical and strategic planning and railroad network control systems.

Expected Outcomes

In this program element, FRA engages in four types of activities regarding train control: (1) Facilitation; (2) Risk Analysis; (3) Testing and Evaluation, and (4) Development of Support Systems. To facilitate the deployment of PTC on the nation's railroads, FRA is taking a lead role within USDOT as the sponsoring agency for Nationwide Differential GPS. FRA is undertaking the analyses to evaluate the risks of collisions and over speed accidents on the corridors that make up the national railroad network, as well as to evaluate the risks of the various technologies that comprise PTC. FRA will undertake the necessary testing and evaluation to confirm the integrity of the various PTC demonstration programs when they become operational, and will establish facilities where further testing and evaluation can be carried out. Finally, Congress directed FRA to initiate the development of tactical traffic planners, one of the key support systems for PTC, needed to obtain the business benefits. FRA proposes to expand that activity into the development of strategic traffic planners as well.

Expected outcomes will include a better understanding of new advanced train control and dispatching systems and technologies; location and tracking systems; new methods of monitoring and control of operationally related railroad assets; such as switches, and remote gathering of right-of-way integrity information. Outcomes will be geared towards the safety issues of such new technologies, when applied in the railroad industry; and when warranted, demonstrations of the new technologies to validate potential risk reduction or mitigation benefits.

The PTC demonstration projects, a key element of FRA's overall program of train control activities, are described in Section 5.1 of this Plan.

Project Descriptions

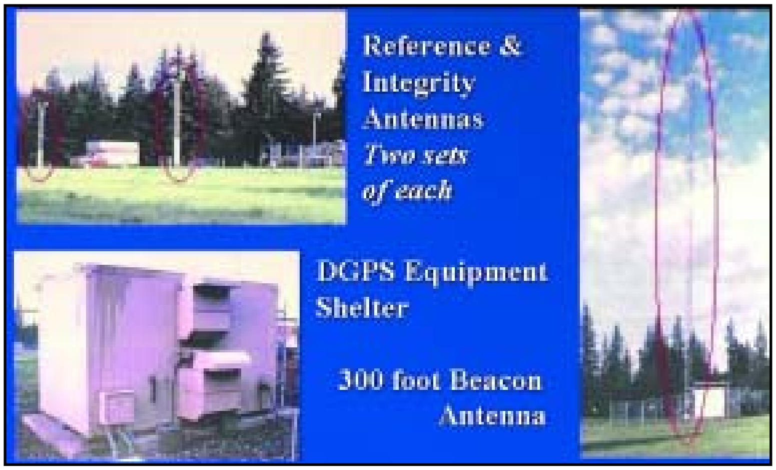
NATIONWIDE DIFFERENTIAL GPS

Nationwide Differential GPS (NDGPS) is described in Chapter 2 as an element of Intelligent Railroad Systems. NDGPS is a joint project of the FRA, the U.S. Coast Guard, the Federal Highway Administration, and the Office of the Secretary of Transportation; and is now being implemented as an expansion of the Coast Guard's Maritime DGPS network. By the end of 2001, approximately 80 percent of the area of the contiguous 48 states will be able to receive an NDGPS correction signal from at least one NDGPS transmitting site. By the end of 2004 all the territory of the contiguous 48 states will receive the signal from at least two transmitting sites.

In July 1999, FRA published a report to Congress, entitled *The Department of Transportation on Civilian Use of the Global Positioning System (GPS): The Nationwide Differential Global Positioning System and Additional Civilian GPS Signals.* It states that FRA established the Federal requirement for NDGPS because of its need for a location determination system for the PTC safety initiative. It also noted that NDGPS would also play a role in the national Intelligent Transportation System program by helping to improve the effectiveness and efficiency of its

Figure 4.6.1

GWEN Site Converted to NDGPS, Appleton, Washington



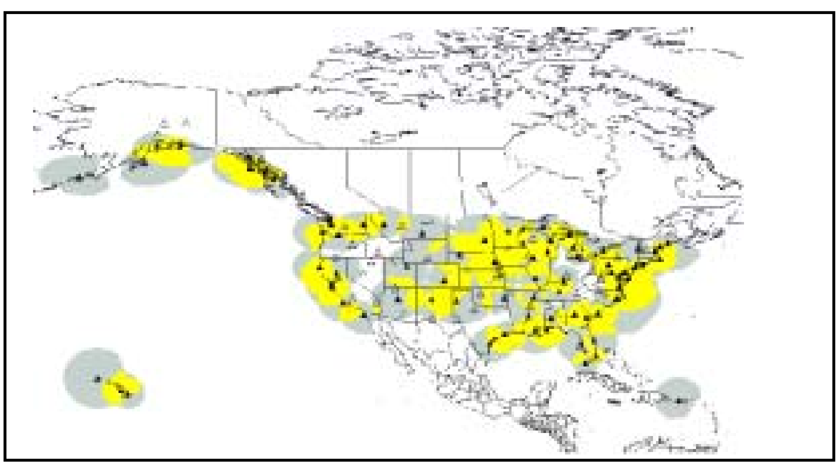
services. Full nationwide deployment of NDGPS would significantly aid the development and deployment of PTC systems by providing an affordable, uniform, continuous, accurate, reliable, secure, real-time location determination system throughout the United States. NDGPS provides a GPS integrity monitoring capability; it gives an alarm to users within 5 seconds of detecting a fault with the signal from any GPS satellite.

Public Law 105-66, Section 346 (October 1997) authorized the Secretary of Transportation to establish, operate, and manage NDGPS to promote public safety. Congress subsequently appropriated funds to the Coast Guard in FY1998 authorizing them to take possession of decommissioned Ground Wave Emergency Network (GWEN) sites from the Air Force, and directed them to begin implementation of the NDGPS. Neither the capabilities of, nor the need for, NDGPS for railroad train control purposes were altered by the elimination of Selective Availability (the intentional degradation of the signal) from the GPS Standard Positioning Service by Presidential directive on May 1, 2000.

When completed, the NDGPS network will number 86 transmitting sites (including 15 in Alaska) and NDGPS Master Control Stations in Alexandria, Virginia, and Petaluma, California. By the end of 2001, 23 of these transmitting sites are to be operational. The new sites are being integrated into the Continuously Operating Reference Station and Precipitable Water Vapor System networks operated by the U.S. Department of Commerce.

Figure 4.6.2

NDGPS Coverage—End of 2001



The installation and implementation of NDGPS across the continental United States and Alaska, is described in detail in the 1999 Federal Radionavigation Plan. It is another component of the National Science and Technology Council's "National Intelligent Transportation Infrastructure" initiative; and is a key element in supporting the Strategic Goals of the *U.S. Department of Transportation Strategic Plan 2000-2005* to improve safety, mobility, economic growth and trade, human and natural environment, and national security. NDGPS will help reduce transportation collisions and fatalities, reduce travel and shipping times, increase overall transportation system throughput, and reduce transportation operating costs. The integrity and positioning information from NDGPS will also be very valuable to those who are engaged in strengthening the security of the nation's surface transportation modes in the aftermath of the recent terrorist activity.

POSITIVE TRAIN CONTROL ANALYSES

Corridor Risk Assessment

Projects to identify which, if any, railroad corridors might benefit from PTC on more than an average basis are nearing completion with development of the geographical information system and accident location databases and the model specification for accident prediction, definition of comparison groups, and consequence estimation. Included is development of a risk identification model that uses the FRA's railroad network GIS platform, coupled with other relevant data such as passenger and freight (including hazmat) traffic patterns, detailed track and signal system configurations, population densities along the line, and the specific accident locations.

Risks of Signal and Train Control Devices

The objective of this program is to develop methods to mitigate potential hazardous failures in the signal systems that are in common use today. Technological advances, particularly in the application of embedded microprocessors and high-power electronics, have resulted in many wayside and train-borne systems having interfaces among signal, train control, communications, and power control functions. One element of this project is to explore more reliable methods to detect train presence. This is of vital importance to the overall safety of a train control system and for preventing collisions at highway-rail crossings.

This project will investigate attributes of microprocessor-based and other advanced signal and train-control systems. It is designed to evaluate current regulations governing such systems, and provide guidelines for development of new regulatory language or other viable regulatory or auditing alternatives to ensure minimal requirements that would guarantee the level of safety of these systems to be the same or better than more conventional systems.

Work will lead to guidelines and recommended practices for safety validation of software-driven and other advanced technology train control systems. The safety-relevant implications of latent faults in electrical and electronic systems affecting train propulsion and control require procedures for testing and validating the safety of these new systems. Research in this area needs to be conducted from a systems perspective. Of particular importance is ensuring the electromagnetic compatibility among all interrelated systems, so that neither causes ill effects upon each other.

Human Reliability Analysis in PTC

The reliability of complex systems is now a routinely analyzed aspect of systems engineering. However, while reliability analyses have been routinely performed on electrical, mechanical and chemical systems for many years, it has only recently been recognized that to minimize the probability of system failure, human reliability must also be considered. This project, also described in Section 4.2 of this Plan, will, in consultation with the Office of Safety and the

Railroad Safety Advisory Committee (RSAC) on PTC, determine the critical human failure modes in emerging PTC technologies and quantify the human failure probabilities. This project is currently examining the Communications-Based Train Management system of CSX and is expected to continue into FY 2005.

TESTING AND EVALUATION OF POSITIVE TRAIN CONTROL SYSTEMS

As various train control concepts are installed and tested around the country, FRA proposes to participate in their testing and evaluation. An example of such participation is FRA's involvement in varying degrees in the ongoing PTC demonstration projects in Michigan, Alaska, South Carolina, and Illinois. The dynamic performance of the systems will be tested to confirm braking curves, headways, and improvements in meets and passes. Handling of the highway-rail intersections will receive special attention. The evaluations will include reviews of the safety documentation provided by the system developers and an assessment to determine if actual operation in the field is consistent with that described in the documentation. Verification of the "robustness" and "fault tolerance" of the new systems will be determined.

FRA is installing a Vehicle Tracking System at the TTC with three objectives in mind: (1) improve the safety of operations at TTC; (2) improve the efficiency of operations at TTC; and (3) provide a testbed at TTC for testing and validating various PTC architectures and components. The project includes the installation of a digital communications network at the TTC. It also includes equipping locomotives; track maintenance and inspection equipment; and road vehicles with GPS/DGPS receivers, data radios, and display screens to permit transmission of location and velocity information to the TTC's Operations Center and to receive instructions and information messages. A demonstration system that tracks three vehicles is currently operational, and the full system is planned for completion in FY 2002.

TACTICAL AND STRATEGIC TRAFFIC PLANNERS

Tactical and strategic planners are described in Chapter 2, Intelligent Railroad Systems. Congress, recognizing that there is growing traffic congestion in high density corridors that has resulted from recent consolidations in the rail industry, directed FRA to undertake the development and deployment of such systems to enable railroads to manage the flow of rail traffic and avoid congestion and jamming. In FY 1999 - 2000, Congress earmarked funds for the development of algorithms for a tactical traffic planner to optimize meet-pass planning, along with building the interfaces with computer-aided dispatching systems.

To optimize the running time, capacity, and asset utilization benefits from tactical and strategic traffic planners, the planners should be installed along with PTC systems that can provide the precise train location and speed information so that the TTP and STP have a timely and accurate view of operations and can plan most effectively. The PTC systems then provide the capability to implement the optimum plans by transmitting operating authorities and precise speed control instructions back to trains.

In FY 2003 and 2004, FRA proposes that work on tactical and strategic traffic planners be carried out in such a manner that they can interact with, and be demonstrated with, one or more of the PTC demonstration projects described in Chapter 5. The project should be competed among interested suppliers, and cost sharing would be one of the selection criteria.

TABLE 4.6

PLANNED TIMELINE FOR TRAIN CONTROL PROJECTS

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
Nationwide Differential GPS	●───	────	────	───●	
Positive Train Control Analyses	●───	────	────	────	───►
Testing and Evaluation of Positive	●───	────	───●		
Train Control Systems		●───	────	────	───►
Vehicle Tracking System at TTC	●───	────	────	───●	
Tactical and Strategic Traffic Planners		●───	────	────	───►

4.7 Grade Crossings

Grade crossings are significant contributors to fatalities and injuries resulting from both highway and railroad operations. Railroad passengers and crews, highway users, and even the random bystander, are all exposed to some level of risk from these crossings. Accident data clearly shows that a major portion of grade crossing collisions can be tied directly to human behavioral issues, which is discussed in Section 4.2. Other grade crossing projects related to high-speed rail demonstrations are described in Section 5.3.

FRA's grade crossing research focuses on all aspects of the highway-railroad intersection. One major effort is on first developing a more precise understanding of the risks presented at the crossing and then how best to decrease or eliminate these various risk elements. Also addressed are evaluation methodologies, visual and audio warnings, motor vehicle and train presence detection, crossing geometry, crossing gate and flashing light technologies, the Intelligent Transportation System (ITS) prototype demonstrations, and the impact of the development of the National ITS Architecture. ITS offers the potential for deploying low-cost innovative warning systems that may have greater effectiveness than passive warning devices. In conducting this research, FRA actively coordinates with all other interested parties such as the One DOT Highway Rail Grade Crossing Team, the ITS Joint Project Office, Federal Highway Administration (FHWA), Federal Motor Carrier Safety Administration (FMCSA), Federal Transit Administration (FTA), National Highway Traffic Safety Administration (NHTSA), the Research and Special Programs Administration (RSPA), the Transportation Research Board (TRB), Transport Canada, and the United Kingdom's Railway Safety Organization. The overall goal of this program is to reduce the number of fatalities, injuries, and collisions at grade crossings while increasing the mobility of highway users affected by grade crossings resulting in decreased traveler delays and decreased pollution from idling vehicles.

Why a Priority?

The grade crossing intersection presents a significant hazard to motor vehicle users and pedestrians, as well as to rail passengers and crew. Grade crossings are the site of the greatest number of collisions and injuries, and the second greatest number of fatalities in the railroad industry. Although declining, trespasser fatalities now exceed fatalities at grade crossings. In 2000, there were a total of 3,502 incidents at both public and private grade crossings, resulting in 425 fatalities and 1,219 injuries. With the increase in development of high-speed passenger rail corridors, the risk posed by grade crossings will become even greater due to the fact that rail passengers will be susceptible to injury and fatality.

Significant progress has been made over the past 25 years in improving the safety of public highway-rail grade crossings. Even though both motor vehicle and train traffic have increased, collisions at grade crossings have declined by 71 percent, fatalities by 56 percent, and injuries by 67 percent. Even though all these trends are positive, the challenge is to continue to improve the safety of grade crossings as they represent a significant portion of the overall risk from highway and railroad operations. Many of the collisions occurring at grade crossings are catastrophic and highly visible.

Approximately 38 percent of all public crossings are equipped with flashing lights and gates, yet they account for approximately half the total collisions. This is because the higher motor vehicle traffic volumes at these crossings increase the potential for collisions. The other half of the total accidents occur at the 62 percent of the public crossings equipped only with passive devices, such as crossbucks and stop signs.

Objective

The primary objective of the grade crossing R&D program is to identify those technologies, methodologies, and hardware that will continue the downward trend of crossing collisions and fatalities.

Enhancing grade crossing risk analysis tools to more effectively allocate limited R&D and capital dollars is one of the first efforts. Specifically, existing asset allocation tools for determining grade crossing treatments will be updated with the development of a more complete set of risk analysis tools. These tools will be used to more effectively review crossings for their risk contribution be it a new planned high-speed passenger corridor or for a state's entire grade crossing inventory. Evaluation and investment analysis tools will also be used to direct the R&D program into specific grade crossing risk reduction strategies, technologies and procedural guidance.

Expected Outcomes

The expected outcomes of the research program are a reduction in the actual number of collisions, fatalities and injuries. This was identified as a major goal of the DOT Grade Crossing Safety Action Plan, published in 1994, and by the One DOT Highway-Rail Grade Crossing Team. In addition, Federal and State governments will be able to make more effective use of their limited resources, provide better driver education programs and develop more effective counter-measures for crossings. The development of Intelligent Grade Crossings and other ITS technologies should result in a significant reduction in delays to motorists and resulting air pollution.

Project Descriptions

The grade crossing program examines the evaluation methodologies, technologies, and hardware that could reduce hazards at grade crossings and reduce the probability of collisions. The projects are organized into five categories:

1. **Core knowledge.** This activity assembles—in convenient, accessible form—past research results, existing statistical insights, and basic data on accident causation. This readily available information will flow to the states and railroads for deployment purposes, and back to FRA and related agencies for use in directing their future research efforts toward high-payoff projects.
2. **Project evaluation.** To speed up the transfer of results in the making, this initiative will bring together all the project evaluation tasks and develop guidelines for future evaluation work. Most of these project evaluations pertain to field treatments—demonstrations of new grade crossing safety enhancement systems and components.
3. **Improved hardware.** This activity examines new technology prototypes, systems, and components that have the potential to improve the safety at both passive and active grade crossings, and include technology transfer initiatives from other modes of transport.
4. **Projects related to ITS and Positive Train Control (PTC).** This initiative will address FRA's efforts to improve grade crossing safety through state-of-the-art tools for both highway and train control and communications—with highway traffic through ITS, and with railroad traffic by PTC. There will be a special focus on the application of ITS at passive crossings, an issue highlighted by the NTSB.

5. **Other Federal and International Activities.** Other offices within FRA, along with FHWA, FMCSA, FTA, RSPA, Transport Canada, Australia, and the United Kingdom are carrying out grade crossing research, development, and demonstration projects that are complementary to those being carried out as a part of this Plan.

CORE KNOWLEDGE

Crossing Project Evaluation and Investment Analysis

The Grade Crossing Research Program has been evaluated through a five-step, "fault-tree" process, described in Chapter 3, with the objective of developing an explicit rationale for project selection and program development. Results from this ongoing effort will help direct the grade crossing program through and beyond year five of this plan. Three projects that ranked high in both the likelihood of success and the safety or regulatory impact of the research are the following:

Evaluation of effectiveness of barrier systems to preclude right-of-way incursion - This project examines the effectiveness of barrier methods such as median barriers with two-quadrant gates and four-quadrant gate systems to reduce accidents at crossings primarily attributed to driver action (drove around or through the crossing equipment or did not stop). The research is aimed at application of new technology to improve the effectiveness of warning systems and will provide supported statements of warning device effectiveness. These estimates could then be used in a resource allocation model to develop cost/benefit analyses to improve federal funding allocation. One evaluation of a four-quadrant gate system at School Street, in Mystic, Connecticut on the Northeast Corridor, will be completed in mid-2002 for publication.

Development of enforcement guidelines - This project analyzes enforcement technologies and their costs and benefits, and formulates performance guidelines and/or best practices. It reviews and analyzes enforcement-training programs and recommends improvements. This research would provide insight to law enforcement agencies on enforcement issues at the highway-rail intersection. Other potential outputs include identification of training issues for law enforcement and judicial officials. Publication is planned in 2002.

Evaluation of off-track train detection techniques - This project investigates improved train detection techniques that do not rely on railroad track circuits. This research could identify and test lower-cost warning device activation strategies, which implies that more crossings could be equipped with active devices. Publication is planned in 2002.

Grade Crossing Closure

A review will be conducted to document crossing closure successes and failures. A guidebook will be assembled for State agencies to assist them with their efforts to close grade crossings. Publication is planned in 2002.

Study of Foreign High-Speed Rail Technologies

Reports on signaling/control technologies, obstacle detection, grade crossing warning systems, and barrier devices as well as methodologies used for warning device implementation used at high-speed crossings in Europe and elsewhere will be published in 2002.

PROJECT EVALUATION

Four-Quadrant Gate Assessment Model

A theoretical model of safety issues related to the use of four-quadrant gate systems will be developed for state agencies to use when considering the use of upgrading crossings with four-quadrant gates. The model is scheduled to be available in 2002.

Grade Crossing Risk Assessment Methodology

The FRA has guidelines that recommend certain grade crossing warning systems for high-speed passenger service at train speeds of 79 miles per hour and higher. At train speeds in excess of 125 miles per hour, these guidelines recommend grade separation or closure as the only acceptable treatment. The risk assessment methodology examines the risk to motor vehicle occupants and railroad passengers and crew posed by these guidelines in order to provide a quantitative basis for specifying the nature of improvements to be made at crossings. The assessment considers the risks and costs associated with alternative warning device options as a function of train speed, train type, collision type, and crossing characteristics such as highway traffic volume and type of existing warning device. The analytical model developed to assess the risks of various warning and train protection alternatives was used to evaluate New York State's Empire Corridor and the first phase of the North Carolina Sealed Corridor Program. It will be applied to the California high-speed corridor and the Gulf Coast Corridor to help the States develop their grade crossing improvement programs. The model will also be combined with a cost-benefit methodology to develop a prototype generic application as a user-friendly tool for evaluating proposed improvements to high-speed corridors.

Evaluate Whistle Ban Impacts

A draft rule to allow communities to institute whistle bans has been published by FRA's Office of Safety, and the necessary supplemental safety measures have been defined. Once the final rule is developed and whistle bans go into effect, those locations will be video-monitored to measure the effectiveness of the supplemental safety measures in the new quiet zones. Video monitoring is currently being conducted at a single crossing in Spokane, Washington, that is equipped with a non-mountable median barrier. Data collection was initiated in 1998 and will continue into 2002. Recorded video data collected to date indicate that the barrier has been effective in reducing violations.

Video monitoring is also being conducted at three grade crossings in Yakima, Washington, equipped with various supplemental safety measures as specified in the whistle ban guidance to determine driver behavior. Data collection efforts were initiated in September 2000, and will continue for two years.

Standardize Test Evaluation Procedures

Evaluation of field tests of new technologies requires significant resources and must identify all relevant issues in the evaluation plan prior to testing as well as be able to offer comparisons of various technologies. This research will establish the contents of an overall evaluation methodology to ensure that all research tasks are included and that all safety effectiveness issues are addressed. Additional work will develop standardized before/after evaluation criteria.

IMPROVED HARDWARE

Grade Crossing Illumination Guidelines

According to the 2000 grade crossing accident statistics, "vehicle-run-into-train" accidents continue to account for approximately one-third of night-time crossing accidents. Poor visibility of the crossing and of the train within the crossing can contribute to these kinds of accidents. A draft final report and brochure on the investigations of illumination systems to enhance the visibility of crossings and passing trains at both active and passive grade crossings was issued in 1998, and the final report and a brochure will be published in 2002.

Locked Gate at Private Crossings

A project being carried out with the New York State DOT will examine the use of a security gate, kept in the lowered position, for use at low-volume, private crossings. The gate will be connected into the train control system so that the gate will not rise when a train is approaching. Another project with Oregon DOT will examine the use of various gates and communication systems for use at low-volume private crossings. The United Kingdom's experience with this technique will be investigated to complement these projects.

Optimal Acoustic Warning (Train Horn)

This project will build upon the earlier train horn research to optimize the sound quality and effectiveness of horns for use on locomotives or in wayside horn systems, while minimizing the noise pollution in surrounding communities. This project is to be completed in 2002. In addition, Transport Canada is also investigating this issue and their experience will be examined to complement this research.

Train and Vehicle Presence Detection Study

FRA has joined with FHWA and the AAR to examine alternative train and highway vehicle detection technologies. A request for technical information was released in late 1998, with a review of submittals in early 1999. Testing was completed at TTC during the fall of 1999. The project continued in 2000 examining test results, completing the final evaluation report, and proposing tests for new technologies as they arise. The publication will be available in 2002.

Neural Network/Video Extraction

Under the HSR IDEA program sponsored by TRB, a neural network-based video content extraction system has been developed to detect obstacles in a crossing and to determine if a train occupies the crossing. A field demonstration of the system will be conducted with the Florida Department of Transportation on the Southeast Florida Rail Corridor to evaluate the video image interpretation abilities of the system in all kinds of weather and train operating conditions. This demonstration is to be completed in 2002.

Intrusion/Obstruction Detection

Intrusion detection systems use a variety of technologies to determine if an obstacle such as a highway vehicle is blocking a crossing, and can also be used to monitor the railroad right-of-way in general. Intrusion detection systems may employ various detection technologies such as inductive loops, magnetometers, microwave, radar, video systems, or fiber-optic sensors imbedded in rail structures to detect the presence of a vehicle or other obstacles. Several of these technologies are employed in Europe and Japan. A research workshop was held in 1998 and Proceedings became available in 2001. This project will support the development of systems requirements for obstacle/intrusion detection devices and is scheduled for completion in 2002.

Improved Barrier Deployment Systems

This project will examine the latest technologies in electro-mechanical actuators and power electronics, which can offer advantages for the development of improved barrier deployment systems. Communication linkage to the railroad maintenance office as well as highway traffic control will be examined to develop an "intelligent" grade crossing controller with health monitoring. This two-year project is scheduled for completion in 2002.

Photo Enforcement

Photo enforcement holds significant potential for achieving greater compliance by motorists of safety laws at crossings. A synthesis of techniques, results and effectiveness of photo enforcement, will be developed and will include work by NHTSA and FTA. In 2001, the status of the use of photo enforcement at grade crossings was released in the form of a white paper.

Passive Crossings Initiative

The National Cooperative Highway Research Program is conducting a study: Recommended Traffic Control Devices for Highway-Rail Grade Crossings, which is examining the use of passive crossing devices. A One DOT Technical Working Group has been organized to respond to the NTSB's recommendations on passive devices. FRA plans to evaluate the results of these activities and develop a program to examine innovative signs and warning systems at passive crossings. These could include variable message signs tied into driver information systems, and other advanced ITS systems. The TRB's Committee on Rail-Highway Grade Crossings, in collaboration with Monash University and the Seventh International Symposium of Highway-Rail Grade Crossings, sponsored a symposium in February 2002 in Melbourne, Australia, to focus research in the area of passive crossing solutions. This experience will help guide FRA research and may initiate complementary exploration of this topical area with Australia.

PROJECTS RELATED TO INTELLIGENT TRANSPORTATION SYSTEMS (ITS) AND POSITIVE TRAIN CONTROL (PTC)

ITS is the application of new communications, computer, and sensor technology to highways and transit systems, and the careful integration of system functions to provide more efficient and effective solutions to multimodal transportation problems. The goal of ITS is to provide a seamless, multimodal, and nationwide transportation system. Development of the National ITS Architecture, which is the framework that addresses all ITS user services, and defines the subsystems and data flows (i.e., information that must be shared between subsystems) required to make ITS work, has been the first step in achieving this vision. In particular, the technologies and operations needed for a transportation system that will satisfy the requirements of the 31 user services are defined in the architecture. Two user services deal directly with grade crossings: #30, Highway-Rail Intersections, and #31, Archived Data.

Highway-Rail Intersections (HRI) User Service #30

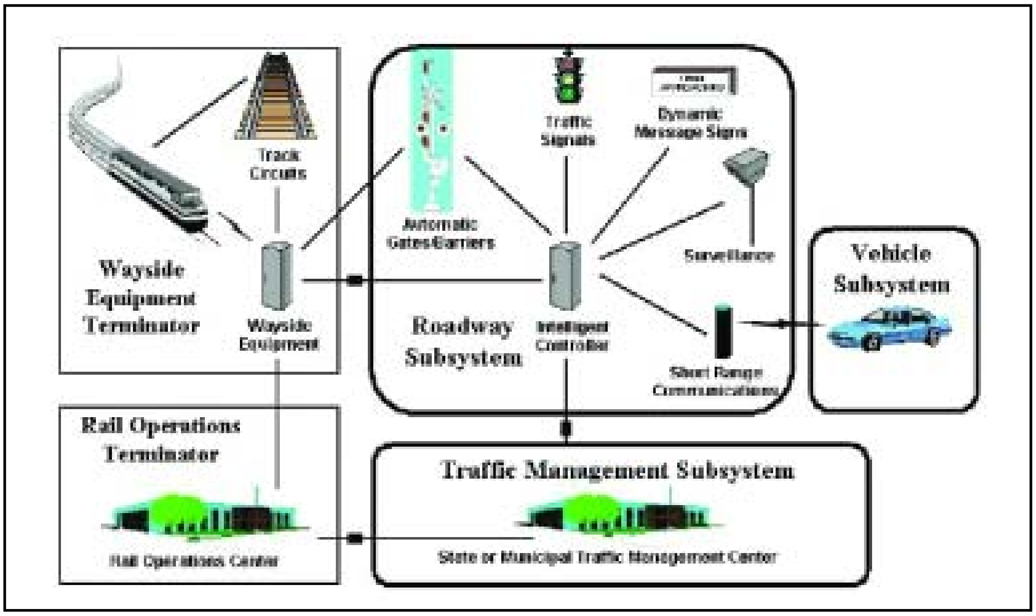
The integration of the railroad operating systems with the traffic management systems through the ITS Architecture is shown in Figure 4.7.1. This architecture was developed through a consensus process involving the AAR, ASLRRA, American Association of State Highway and Transportation Officials (AASHTO), states, ITS America, FHWA, and FRA. The result is a system that would have the capability for getting advance warning of approaching trains through interconnected information systems that link the motorist to the traffic management and rail operations systems. It also allows for the capability of warning the locomotive engineer of obstacles or trapped vehicles at grade crossings, and potentially, for trespassers along the right-of-way.

A number of ITS-related grade crossing projects were initiated prior to the establishment of the national architecture. While all seem to have worked, providing safety benefits, and providing insights into the applicability of specific technologies, none were interoperable with one another. Consequently, these projects are no longer being supported, and only those projects that are compatible with the national architecture will be supported in the future.

As the next step in the ITS Program, FRA and the ITS Joint Program Office have asked Standards Development Organizations, including the Institute of Transportation Engineers

Figure 4.7.1.

Architecture of ITS User Service #30 — Highway-Rail Intersections



(ITE), the Institute of Electrical and Electronic Engineers, AREMA, AASHTO, and others, to develop the standards necessary for implementing ITS at grade crossings nationwide. These standards will be the basis for projects that will tie grade crossing warning systems to local traffic management systems and will include communication to the PTC systems now being developed to increase safety for both motor vehicle users and rail passengers and crewmembers. These standards will also be turned into regulations by FHWA for the purpose of funding decisions. No Federal funds would go to the HRI projects not meeting the standards.

Archived Data User Service (ADUS) #31

Real-time data from traffic and transit operations can be archived and used for purposes other than in ITS control strategies. By archiving the detailed data collected, more accurate analyses for planning, research, performance monitoring, and policy purposes can be conducted at much lower costs. ADUS was the latest user service to be adopted into the National ITS Architecture in September 1999.

Standards development is also underway for ADUS, and it will provide guidance in system design and promote the integration of ITS with traditional information systems and ensure consistent deployments of archives within regions as well as throughout the nation. To implement ADUS, a Strategic Plan for ADUS Standards was one of the first specific activities identified. Many of the other activities in the ADUS Program Plan will feed the standards efforts as more is learned from research and case studies. Standards will expedite national level analyses that rely on comparing conditions across the country in a consistent manner as well as allow historical comparisons and trend monitoring since data definitions will remain stable over time. They also will allow comparison of operations among various regions.

Intelligent Grade Crossings

As noted in Chapter 2, Intelligent Grade Crossings are those locations where ITS for roadways come together with Intelligent Railroad Systems, and in particular, PTC systems. PTC systems, unlike traditional railroad signal systems, provide continuous information on train location and speed. FRA, working with the ITS Joint Program Office, intends to sponsor Intelligent Grade Crossing projects on railroad corridors in Illinois and Alaska where FRA-sponsored communication-based PTC systems are being implemented and demonstrated. A PTC project sponsored by CSX in South Carolina and Georgia is another potential site for an Intelligent Grade Crossing project.

Coordination will take place with the State highway departments so that these grade crossing projects are integrated with other ITS projects currently underway. For example, warning to motor vehicles of oncoming trains, as well as advice on alternate routes to avoid blocked crossings, would be transmitted through the standardized ITS dedicated short-range communications system and displayed on standardized in-vehicle information displays and roadside variable-message signs. Information on the PTC systems being demonstrated is presented in Section 5.1.

Activating Passive Crossings

The National Transportation Safety Board (NTSB) has identified the need for the application of ITS at passive crossings. Passive crossings are those that provide no warnings other than static signage—the familiar yellow circular sign advising that a crossing is ahead and the traditional X-shaped "Railroad Crossing" crossbuck at the crossing—and, in some cases, pavement markings.

In general, passive crossings are "passive" because they are low-volume, both for the number of passing trains, and the number of crossing road vehicles. Each crossing has a low likelihood of becoming a crash site. However, collectively, passive crossings account for over half of overall grade crossing crashes and fatalities. While the number of passive crossings has gradually been declining, there are still over 90,000 on public roads. The long-range approach to achieving safety at passive crossings, as envisioned by NTSB and others, may not involve any technology at all at the crossing itself.

Table 4.7.1.

Characteristics of Active and Passive Grade Crossings

	Active	Passive	Total
Average Trains/Day	13.7	6.2	
Average Motor Vehicles/Day	3,676	320	
Crashes - 2000	1,840	1,688	3,502
Injuries - 2000	567	652	1,219
Fatalities - 2000	199	216	425
Number of Public Crossings	72,272	83,098	155,370
Number of Private Crossings	1,436	99,435	100,871

Source: NTSB and FRA Office of Safety

The long-range vision of rail operations includes rail operations centers that have precise real-time information on the location of all train, their direction of travel, and their speed. The long-range vision of automotive ITS includes a continuous wireless link between a motor vehicle and its ITS service provider that delivers precise real-time information on the vehicle's planned route and its current location. In the context of a common, appropriately detailed, and accurate digital map of roadways and railways, rail traffic control centers can apprize ITS service providers of the approach of all trains to all crossings. Service providers can then warn client vehicles when they are approaching a crossing that a train is crossing or approaching. In the extreme, onboard driver assistance systems can automatically slow or stop a road vehicle that is approaching a crossing in an unsafe manner. Conversely, service providers can advise rail operations centers of road vehicles that have become stuck or disabled in a crossing so that trains could be slowed or stopped to avoid a collision.

The primary problem with this long-range vision is that it is very long range. If the necessary in-vehicle equipment began to be installed in every new vehicle starting today, it would still take well over ten years before the great majority of the private car fleet was equipped (significantly longer for the commercial vehicle fleet). Ubiquitous infrastructure for service provider communications with equipped vehicles will also not happen all at once, nor will the railroad infrastructure for reliably tracking all trains. So, even if this long-range vision comes to pass, interim solutions will be needed for a long time. These interim solutions need to work well, be cost-effective, and be highly reliable.

For any interim solution, there are two fundamental components for warning road vehicles of approaching trains: the train's approach needs to be detected, and the road vehicle needs to be advised of the train's approach. In addition, there needs to be a triggering mechanism that, once a train is detected, causes the road vehicle advisory to be activated. FRA plans to undertake investigation and testing of the applicable technologies and develop demonstration projects involving passive crossings in several areas of the country.

Long Island Rail Road Demonstration

Another concept for an intelligent grade crossing is being developed by Alstom for the Long Island Railroad with FHWA funds and with active FRA participation. This system will connect the local grade crossing gate controller to, both the train control system and the highway traffic signal system, to control the traffic signals and provide information to motorists on large roadside variable-message signs. The goal of the project is to minimize traffic delays in the vicinity of commuter rail stations in suburban areas while improving safety. This project began in 1996, and the demonstration of the system was conducted in June 2001. The next phase of the research is to conduct a benefit-cost analysis on the system as it relates to the specific conditions along the LIRR.

Four-Quadrant Gate with Obstruction Detection

Four-quadrant gates with an intrusion detection system have been installed with a link to the Advanced Civil Speed Enforcement System for train control on Amtrak's Northeast Corridor (NEC) at School Street in Groton, Connecticut. This system will be installed at six additional high-speed locations on the NEC. The demonstration is complete. A report will be published in 2002. Further details are presented in Section 5.3.

Advanced Activation of Crossing Gates

The Incremental Train Control System (ITCS) installed on a portion of the Detroit-Chicago high-speed corridor incorporates a feature to permit trains to operate at higher speeds by closing the crossing gates earlier than they would normally be closed if only the existing track circuits were used. The ITCS system is now operational, and evaluations are underway to determine the effectiveness of this feature, which, if successful, would have applicability on corridors throughout the country. The ITCS project is described in more detail in Section 5.1.

HRI - ITS Strategic Plan

FRA is working with the ITS Joint Program Office, FTA, FHWA, NHTSA, FMCSA, and the Volpe Center to develop a Strategic Plan for ITS Grade Crossings to be completed in 2002. While addressing all the aforementioned research, testing, and standards development activities, it will also address the resources needed to support an overall goal of a nationwide "rollout" of HRI-ITS technology.

OTHER FEDERAL AND INTERNATIONAL GRADE CROSSING ACTIVITIES

FRA Offices of Safety and Policy

The FRA Office of Safety is sponsoring a trespasser prevention video monitoring project in Pittsford, NY, to detect trespassers on a railroad trestle bridge. When trespassers are detected, the local authorities can then use a loudspeaker near the bridge to warn trespassers to leave and send the police to clear the bridge, if necessary. This system was installed in mid-2001 and the evaluation will continue through late 2002.

FRA's Office of Policy has developed a cost/benefit analysis for grade crossing investments within a risk analysis framework that uses the estimated reduction in incidents, fatalities and injuries at a crossing from improvements made at a crossing. Dollar values for full range of benefit categories, and financial data for evaluating and comparing alternative investment strategies are provided. This program, called *GradeDec2000* and available on the FRA web site www.fra.dot.gov, can be used to help guide state agencies in utilizing their limited grade crossing improvement resources, and will be used as an element in an advanced corridor risk assessment model to be developed.

The Office of Policy is undertaking a benefit cost analysis of State laws regarding highway-rail warning devices and educational programs. This effort is planned to provide guidance to the FRA Office of Safety to develop model State laws for grade crossings similar to the document published in 1998 on model laws for trespasser and vandalism.

One DOT Highway Rail Grade Crossing Team

In early 1998, the One DOT Highway Rail Team was organized to be the overall research coordinator for grade crossings across all modes for the department. It represented a reconstituting of the Highway-Rail Crossing Safety Team organized in 1994, and actively involves FRA, FHWA, FTA, NHTSA, FMCSA and OST. The goal of the new team is to reduce the number of fatalities, injuries and incidents by 50 percent by 2008, using 1996 as the baseline year.

One DOT Technical Working Group

Another team, the One DOT Technical Working Group, was initiated in 1999 to develop guidance to assist state and local engineers in determining the most appropriate traffic control device or grade separation for highway-rail grade crossings. Included on the team are representatives from State and local governments, AASHTO, ITE, NTSB, TRB as well as rail unions, suppliers and other organizations. The need for "warrants" for grade crossing devices has been recognized for several years as an important research topic by both FRA and FHWA, and FRA is the co-leader with FHWA of the Technical Working Group. A draft final report was issued in June 2001 and is in review. A final report is intended for publication in 2002.

Federal Highway Administration

The warning devices at grade crossings are traffic control devices that fall under the jurisdiction of the FHWA, and the specifications for the devices are provided in the Manual of Uniform Traffic Control Devices (MUTCD). The FRA and FHWA have worked together for years, both formally and informally, to make grade crossings safer. FHWA has several research projects underway, and sections 8 and 10 of the MUTCD dealing with grade crossings and light rail transit grade crossings, respectively, have been revised and published as part of the Millennium Edition of the MUTCD, now available on its own web site http://mutcd.fhwa.dot.gov/kno-millennium_12.18.00.htm.

Federal Motor Carrier Safety Administration

Formerly a part of the FHWA, the new Federal Motor Carrier Safety Administration is working with the American Trucking Association and Operation Lifesaver to improve the safety within the commercial driving profession. A training video was produced to educate commercial motor vehicle drivers on grade crossing safety issues. Other activities include drafting rules governing the safe clearance space necessary for trucks at grade crossings, preparing final rules governing disqualification of commercial drivers for violating Federal, State, or local laws pertaining to grade crossings, and photo enforcement.

Federal Transit Administration

FTA's *Transit Research & Technology Five-Year Plan* addresses grade crossings as one of its safety topics. The FTA is an active partner with the FRA through the One DOT Highway-Rail Grade Crossing Team. The technologies and strategies being examined include integration of highway-rail traffic control systems and roadway traffic management systems, information management of warning of trains to motorists and pedestrians, improvement of passive and active warning signals for light rail and commuter rail transit, development of track-train presence detection systems, and "health" monitoring of grade crossing equipment. FTA's new Joint Partnership Program for the Deployment of Innovation offers the potential to introduce new technology more quickly with Federal support, and FRA will work with FTA on innovations dealing with grade crossings.

Potential International Joint Activities

Transport Canada

Transport Canada, in partnership with provincial and municipal governments, railroads, unions, police agencies, and other safety organizations, has launched its *Direction 2006* strategy for improving transportation and safety in Canada. One of the seven working groups deals with grade crossings. Their objective is to reduce the number of highway-rail grade crossing collisions and trespassing incidents by 50 percent by the year 2006 through research in behavior factors and technology.

Canadian experience with grade crossing incidents and fatalities is similar in proportion to its population to that experienced here in the U.S., or approximately one-tenth of that of the U.S. Many of the research topics in the Transport Canada plan are similar to those underway or planned in the U.S., including developing a risk mitigation approach to grade crossing safety, accident causal analysis and countermeasures effectiveness, analysis of trespassing accidents, second train warning signs, locomotive horns, and low cost active systems to improve passive crossings. FRA is currently developing a Memorandum of Understanding to solidify a cooperative research program.

United Kingdom

As part of the rail privatization efforts in the U.K., the Railtrack organization now owns and maintains most British railroad assets. Railway Safety is a not-for-profit quasi-independent organization, funded by the government, within Railtrack. Railway Safety has responsibility for assisting in establishing safety plans for railroad operations, for monitoring safety performance, and for performing safety research for railroads in the U.K. A significant railroad safety research program is being funded (£75 million over five years, or about $125 million) and the leaders of Railway Safety are interested in establishing a formal memorandum of agreement to share research activities and results with FRA. FRA is currently developing a draft Memorandum of Understanding to solidify a cooperative research program.

TABLE 4.7.2

PLANNED TIMELINE FOR GRADE CROSSING PROJECTS

	FY2001	FY 2002	FY 2003	FY 2004	FY 2005
Core Knowledge					
Grade Crossing Closure	●———	——●			
Foreign High-Speed Rail Systems	●——●				
Project Evaluation and Invest. Analysis	●———	————	————	————	———▶
Evaluation					
4-Quad Gate Assessment Model	●——●				
Vehicle Arrester Net Evaluation	●——●				
Risk Assessment Methodology	●———	————●			
Evaluation of Whistle Ban Effects	●———	————●			
Standard Test/Evaluation Procedures	●———	——●			
Improved Hardware					
Illumination Guidelines	●———	——●			
Locked Gate/Private Crossings	●———	——●			
Optimize Acoustic Warning	●——●				
Train Presence Detection	●——●				
Neural Network/Video Detection	●———	————●			
Improved Barrier Deployment System	●——	————	——●		
Photo Enforcement	●——●				
Innovative Passive Systems		●———	————	——●	
ITS/PTC					
Intelligent Grade Crossings	●———	————	————	————	———▶
Activating Passive Crossings	●——	————	————	————●	
Long Island Railroad	●——●				
4-Quad Gate w/Obstacle Detection	●——●				
Adv. Activation of Gates	●———	————●			
ITS Strategic Plan	●———	——●			

4.8 Hazardous Materials Transportation

Major improvements in the safety of hazardous materials (hazmat) transportation on railroads have been made in the last 25 years. In the late 1960's and early 1970's, there were a number of very serious hazmat rail accidents. As a result, the FRA, along with the AAR and the railroad supply industry, through the Railway Progress Institute (RPI), entered into a cooperative research program to improve tank car safety. Through research and testing, methods were developed to better protect tank cars in fires and collisions. Results from these projects helped the FRA to develop regulations for thermal protection systems, double shelf couplers, large capacity pressure relief valves, and head protection. The number and severity of railroad accidents involving release of hazmat has been greatly reduced as a result of these safety improvements. The decline reflects: (1) a remarkable improvement in the railroad accident/ incident rate, (2) safety research and improvements made to nonreclosing pressure relief devices on tank cars, and (3) a more vigilant "pre-trip" shipper inspection of tank cars as a result of a 1995 USDOT rulemaking.

Why a Priority?

There are more than 240,000 tank cars in the North American railroad car fleet, which represents more than 18 percent of the railroad car fleet. Tank cars carry most of the railroad-hauled hazmat, but some hazmat is also carried in covered hopper cars, intermodal containers, and piggyback trailers. Rail shipment of hazardous materials accounts for 18 percent of the ton-miles of all hazardous materials shipped.

In 2000, 725 of the reported railroad accidents involved train consists transporting hazardous materials. Out of 6,942 cars in those train consists that containing hazmat, 979 of the cars were damaged and 75 cars released hazmat. This resulted in 5,251 people being evacuated. One fatality (a result of the accident, not due to a hazmat release), 82 injuries, and over $26 million in property damage were reported. Therefore, even with the great safety improvements made to tank cars in the 1970s, 1980s, and 1990s, hazmat is still released during accidents. Hazmat is also released in non-accident incidents. RSPA's database shows 711 serious incidents involving rail shipment of hazmat in 2000.

As noted in Section 4.1, the 2001 derailment and fire involving a freight train in a tunnel under Baltimore raised issues regarding the routing of hazardous materials. Even though the safety of hazardous materials movements on the nation's rail network continues to improve and the rate of incidents and accidents is lower than alternative transportation modes, accidents continue to happen. One course would be to ban all hazardous material movements on the railroad network, but the economic cost of such a dictate would be extreme. In addition, such a policy decision could actually increase the overall societal risk as such movements migrate to riskier transportation modes and routings. However, allowing completely free movement of hazmat on the railroad network can also lead to very high costs when rare but high consequence accidents occur. Research is needed to better serve decision-makers with a more detailed understanding of the complex tradeoffs for policies related to hazardous material movements on all elements of the U.S. transportation infrastructure.

Section 21 of the Hazardous Materials Transportation Uniform Safety Act of 1990 called for the Secretary of Transportation to enter into a contract with an appropriate expert body for a study of tank car design. The TRB conducted the study and issued Special Report 243, Ensuring Railroad Tank Car Safety, in 1994. The USDOT and the railroad and tank car industries have taken significant steps to improve the process for ensuring tank car safety in recent years. However, TRB made several recommendations regarding long-range safety goals and strategies.

The government agencies responsible for ensuring tank car safety agreed in principle with the TRB recommendations. The FRA, RSPA, Transport Canada, the various railroads, tank car builders, shippers, and the emergency response community, participated in a two-day cooperative public information meeting in February 1996, to identify future research needs related to tank car safety. Additional meetings have been held to discuss research results and further research needs.

In addition, the RPI-AAR Railroad Tank Car Safety Research and Test Project hosted a Tank Car Research Coordination meeting in November 1996, to gain knowledge and understanding of present and proposed research efforts, sponsored by various trade associations and government agencies within North America. A number of the results from these meetings have been used to guide the FRA's hazmat R&D program and to avoid duplication of research.

Objectives

The objective of the hazardous materials research program is to continue to help minimize the incident rate of leaks, spills, damage to equipment and the environment due to hazmat releases, and to reduce the number and severity of injuries and risk of fatalities to railroad employees and the public.

FRA's hazmat R&D programs for this five-year period will focus on the following goals:

- Hazmat Transportation Safety - Reducing the rate and severity of hazardous materials releases by optimizing manufacture, operating, inspection and maintenance procedures for the tank car fleet as well as the routing of hazmat shipments.
- Tank Car Structural Integrity - Ensuring the structural integrity of tank cars throughout the normal service life and under potential accidental scenarios.
- Tank Car Damage Assessment and Improved Inspection Strategies - Ensuring safety of emergency response personnel when using tank car damage assessment guidelines; developing, improving and quantifying the effectiveness of inspection procedures; and implementing damage tolerance analysis to design tank car structural integrity inspection strategies.

In addition, FRA's hazmat R&D program will provide support to the Office of Safety if it needs to take a more active role in the tank car design approval process as a result of the changing roles of industry partners as the industry evolves.

Expected Outcomes

Typical and expected outcomes from this research program are as follows:

- A comprehensive list of risk tradeoffs related to hazmat shipments on the U.S. railroad network.
- Reduced rate and severity of hazmat releases by applying a systematic approach to utilize available resources to improve safety.
- Improved engineering design practice through validated mathematical modeling capabilities.
- Improved understanding of tank car operating and accident environment conditions.
- Reduced rate of multiple car derailments through the use of improved design shelf couplers.
- Development of use and design parameters for gross-weight tank cars greater than 263,000 pounds.

- Prevention of unwanted hazmat release due to incorrect relief pressure device design, capacity or/and setting.
- Development of effective inspection methods to ensure continued tank car integrity, including documented reliability and sensitivity for the methods used.
- Reduced the risk for emergency response personnel by validating damage assessment guidelines for accuracy, timeliness and applicability.

The results will be documented in reports that will be disseminated to industry. Some of the results will provide the basis for future FRA inspection and maintenance regulations.

Project Descriptions

HAZMAT TRANSPORTATION SAFETY

The safe transport of hazardous materials is dependent on a broad range of factors: the integrity of structural components such as the stub sill and tank shell; the integrity of non-structural components such as fittings and gaskets; the likelihood and susceptibility of the tank car operations to human error; and the behavior under potential accident, collision and derailment scenarios. The goal of this project is to improve the safety and efficiency of the transport of hazardous materials by rail. To achieve this goal, the effect of operating, design, manufacturing, inspection, and repair practices on tank car safety must be understood. Furthermore, these aspects must be considered as a system to ensure that resources are directed toward the improvements that will have the greatest impact on safety.

Hazmat Shipment Routing

This project will investigate the broad area of hazmat shipments on U.S. railroads. The focus of this work will be to move forward from the extensive body of knowledge that exists within the railroad industry as a result of an ongoing effort to reduce the risk component of such shipments. The risk implications of restricting such shipments to certain classes of track, certain levels of train control systems, and low population density areas will be studied. Such studies will also identify the broader effects of such operational changes, such as the effect on system or line capacity for the shipment of all goods. The goal will be to develop a better understanding of the complex risk tradeoffs between various operational and technological approaches to reducing risk exposures from such commodity movements. For example, the concept of rerouting “high risk” movements around major metropolitan areas rather than through them via urban tunnels will be investigated. Specifically for cities such as New York and Baltimore, with known hazardous material exposure, alternatives that would either reroute traffic and/or build new track and tunnels will be studied.

Improved Understanding of Tank Car Operating Environment

A better understanding of the in-service loads to which tank cars are subjected is needed for several reasons. Severe loads that occasionally occur during service can lead to incidents of tank car structural damage or complete failure. The frequency and magnitude of such events is presently not well understood. Additionally, the accumulation of damage over time from many relatively small cyclic forces can also lead to structural damage to tank cars. The tank car industry is in the process of implementing damage tolerance fatigue analysis as a performance based strategy to prevent fatigue failures. Sensitivity studies have suggested that an accurate representation of the loads encountered by tank cars is essential to damage tolerance analyses. Yard impacts and forces on tank cars during in-train accidents are also not presently documented in terms of stresses throughout the load carrying members of the tank car.

Recent advances in microprocessor and telecommunications technology will be used to develop an instrumented car that is capable of being placed into revenue service to measure, record and transmit forces. This car will be used to develop additional data that will be combined with existing Freight Equipment and Environmental Sample Test (FEEST) data to provide a better understanding of the actual load spectrum seen by tank cars. The aim of this project is to gather and analyze such data. This information will be used to improve tank car structural integrity.

Similar research is required for forces developed under extreme impacts in accident conditions. This type data, if it exists, has not been compiled for ready reference. This data is important for use by designers in determining the likely sites of damage and action required. This project will gather this data from literature, industry databases, and application of engineering principles. This data will need to be updated periodically; therefore this will be an on-going project.

Railroad Transportation of Spent Nuclear Fuel

With the renewed interest in finding a repository for long-term storage of radioactive materials (RAM) and spent nuclear fuel, there is a need to revisit issues related to railroad transportation of these materials. Research will focus on the safe transportation by railroad using available accident environment analyses to determine potential forces that may be encountered by the railroad spent nuclear fuel casks if involved in an accident. Current research is focusing on a risk assessment of the safety of transporting spent nuclear fuel in regular freight service versus dedicated train service. This is an on-going project.

Tank Cars Greater than 263,000 pounds Gross Rail Load

The current regulations prohibit transportation of hazardous materials in tank cars with a gross rail load (GRL) greater than 263,000 pounds. However, the railroad industry is moving rapidly in the construction and operation of other railcars with a GRL of 286,000 pounds. Tank car builders and owners are presently submitting applications to the USDOT for the use of these increased GRL cars. The industry's fatigue analysis is performed on these cars using the FEEST-1 or FEEST-2 loading spectrums. The scaling up method used to account for the increased GRL is a linear method. A peer consensus is that longitudinal and vertical coupler loads must be scaled up or changed to account for the increased gross weight of the cars. Before such a requirement may be considered or put in place, a study of appropriate scaling factors must be made. A more thorough understanding of changes in in-train forces with changes in GRL may be developed by a review of past FRA research involving the train operation simulator models, and the 'ADAMS' computer models, and translating those studies to the study of increased gross weight tank cars. The issue of buckling of adjacent light, normal, and heavy tank cars, will also be investigated. The study results will be used as a guide in evaluating future requests for the use of increased gross weight tank cars and railcars, or as a minimum, will direct R&D efforts for the safe transportation of such loads. This research is planned to continue through FY 2004.

Figure 4.8.1

Tank Car Simuloader

Assessment and Validation of the Methodologies for Engineering Reliability

Accidents, tank car structural failures, and the existence of defects in structural components of railroad tank cars, lead the FRA to believe that measures of reliability for tank car components must be defined and detailed reliability assessments on a variety of components should be performed. This type of assessment should be performed for each unique component design to define and document boundaries for the reliable use of each tank car. This project is planned to continue through FY 2003.

The reliability of the tank car may be defined as the probability that, when operating under stated environmental conditions, the tank car will perform its intended function adequately for a specified interval of time. To assess tank car reliability, different modes of tank car failure must be defined and categorized. Although complete and catastrophic failure is easily recognized, tank car performance as a safe packaging of hazardous materials can deteriorate and elements contributing to this deterioration (e.g., corrosion, cracks, pitting, fatigue, changes in material properties) need to be documented. Reliability functions, expected life, hazard functions, and failure rates must to be defined for tank cars. Since the reliability of the tank car will be a function of several design variables and parameters, developing a methodology for combining these random variables into a tank car "strength" function is necessary. The results of this assessment can provide tank car owners with quantitative information to define and document boundaries for the reliable use for each tank car, enabling them to implement guidelines for the maintenance and use of tank cars.

Tank Car Pressure Relief Devices

In the 1980's, the FRA and the tank car industry developed an analytical program for calculating the effects of fire on railroad tank cars for the purpose of selecting pressure relief device type, sizing, capacity, and pressure settings. These procedures were used to predict various parameters, such as the start-to-discharge time to failure, the residual amount of lading and pressure in the tank at time of failure, the time to reach this pressure level, etc. Further work to enhance the program was made in 1992. Additional work is being conducted to further refine and expand the software. This research should be completed in FY 2002.

Flow capacity and rating of tank car pressure relief devices, especially non-pressure or general-purpose cars, requires an understanding of the thermodynamic behavior of the product in fire conditions and the performance of the car. This also is the case for cars carrying "poison by inhalation" material. This project will identify parameters and rules to apply in the formulation of proper relief properties for this type of lading, similar to what has been done for pressure tank cars.

Shelf Coupler Redesign/Height Mismatch Effects

One safety feature found on all tank cars used in hazardous materials service is the double-shelf coupler. These couplers are designed to remain engaged when subjected to forces that occur during switching operations and train accidents.

Before the use of double-shelf couplers, a coupler would become uncoupled in accidents and during normal switching operations, ride up over the draft assembly of a tank car, and puncture the head of the tank. To understand the transmission of forces through the train and the effects of these forces on tank cars, both in normal operation and in an accident environment, a study of the double-shelf coupler is planned. This study, which would continue for several years, would include stress analysis to understand the load paths through the coupler and a look at the coupler/coupler interface and coupler/draft assembly interface as a dynamic system. After such a study, appropriate design and material changes to the shelf couplers may be based upon the known system.

Spills from tank car closures are significant safety concerns of tank car handlers, shippers, owners, and operators. This is mostly a human factor's problem, but should nevertheless, be researched to diminish its effect on tank car integrity. Work will be initiated in FY 2003 to look at unintentional leaks and will continue for several years.

TANK CAR STRUCTURAL INTEGRITY

Structural integrity of tank cars is an important factor in hazmat transportation safety; as the most severe hazmat releases tend to result from a loss of structural integrity, either suddenly in an accident, impact, or derailment, or gradually due to damage accumulated in normal service. The goal of this project is to ensure that the capability of hazmat carriers to maintain structural integrity is understood. This understanding will allow performance-based requirements for design, manufacture, operations, and inspection to be incorporated into tank car regulations and practice, thereby improving the safety of hazmat transport by rail.

Models for Fatigue Damage in Tank Car Structures

One potential failure mechanism for tank car structures is the growth of a fatigue crack to a critical size. Fatigue crack failures can be prevented through periodic inspections. However, the prediction of fatigue crack growth rates is essential in order for appropriate inspection intervals to be determined. Fracture mechanics approaches to predicting fatigue crack growth rates have been employed by other industries, especially the aerospace industry, and can be adapted to the tank car industry. However, additional testing must be performed, and some technical advances might be needed to adapt available methodologies specifically to the tank car industry. For example, baseline fatigue crack growth properties, essential for predicting in-service crack growth rates, are not yet available for all steels used in the manufacture of tank car shells and stub sills. Models for predicting the load interaction effects on crack growth rates have been developed for the aerospace industry, but the tank carload spectrum is very different from the load spectrum for aerospace applications. The existing models will need to be evaluated, and perhaps extended, before they can be applied with confidence to tank car applications. The effect of manufacture, especially welding, on crack growth behavior must also be evaluated.

Effect of Welding on Structural Integrity

Tank car structures are joined by welding. Despite many advances in welding practice over the past decades, cracking due to fatigue or sudden impact is most likely to occur in the vicinity of a weld. Damage in the weld, heat affected zone, or parent material near the weld can be affected by changes in microstructure, residual stresses, or initial flaws that can be induced during manufacture or repair. Furthermore, welds often occur near edges and corners of the structure, or induce changes in cross section geometry, where stresses are naturally high. The effect of welding and stress relief practice on the location and magnitude of residual stresses in tank car structures will be studied through laboratory experiments and numerical modeling techniques. Laboratory tests on the effect of welds on fatigue crack growth rates will be performed. These results will be incorporated into models for crack growth in tank car structures. Advances in nanotechnology will also be evaluated for application to tank car materials. This project will continue through FY 2005.

Models for Damage in Accidents and Over-Speed Impacts

The structural integrity of a tank car shell must be maintained during extreme conditions such as impacts, collisions, derailments and over-speed impacts. Historically, punctures caused by impacts to tank car heads have been the cause of many hazardous materials releases. Results from full scale and part scale impact tests conducted in the 1970s and early 1980s led to regulations for head shields for certain hazardous material tank cars. Further work was conducted in the mid-1980s on tank cars for transporting chlorine and for aluminum tank cars, resulting in the development of a model to predict the puncture of a tank car head. These improvements have greatly reduced the occurrences of tank car head punctures.

Further efforts are needed to evaluate the current models for puncture resistance of tank car heads. The ability to use finite element models to simulate the non-linear (material and geometric) deformations of the tank car shell, jacket, and head shield during impact has improved significantly in recent years. This allows the relative puncture resistance of different designs to be evaluated. However, the deformation at which failure actually occurs is less well understood. Failure models for steels have been developed for the U.S. Navy and the nuclear power industry, including the effect of lading (liquid or pressure) on global deformation behavior. Adapting these models to the tank car environment would lead to a better understanding of failure mechanisms that occur during head impacts and other accident scenarios, and improve the capability to assess the condition of tank cars damaged in accidents. This project is expected to continue for several years.

Tank Car Steels

Materials authorized for use in the construction of tank cars are specified in the regulations. The objective of this project is to develop a performance-oriented specification for steel used in tank car construction. This project will develop a parametric model for the determination and selection of steel for tank car construction. Past research showed that tank car steel properties, for tank car steels in similar service, were not consistent, in that they did not follow definite patterns. A compendium report will be prepared. This project will continue through FY 2004.

Intermodal Tank Integrity

Use of intermodal portable tanks for hazmat is increasing. The containment integrity of such tanks will be reviewed for safety when they are used in railroad service. Enhancements have been made to the integrity of intermodal tanks, but intermodal tank design criteria and performance need to be evaluated in terms of international transportation requirements and size and weight limitations. This research is planned for FY 2002 and is expected to continue for 3-4 years.

Thermal Integrity of Tank Cars

As tank cars age, thermal protection systems deteriorate and insulation materials slump. Current regulations require qualification of thermal systems periodically. However, research is necessary to ensure there is no negative effect on the overall tank car thermal integrity. This research is planned to begin in FY 2003 and continue for several years.

DAMAGE ASSESSMENT AND IMPROVED INSPECTION SYSTEMS

An accurate assessment of the condition of a tank car is essential to the safe transport of hazardous materials. Damage or wear that has resulted from normal operation must be identified at scheduled inspections before such damage leads to failures or releases. Also, the condition of any car that has been damaged in an accident or derailment must be known before a determination of the most appropriate action to ensure the safety of the public, railroad employees, and emergency responders can be made. The goal of this project is to develop, improve, and quantify the capability to assess the condition of tank cars, in repair shops and at accident sites.

In its report on Ensuring Tank Car Safety, the TRB recommended that USDOT should continue to work closely with industry to identify methods for verifying the structural integrity of in-service tank cars, including nondestructive evaluation (NDE) test methods to supplement or replace existing test requirements. Further, the TRB recommended that results from the inspections and tests should be routinely collected to monitor tank car condition, improve test and inspection methods, and enhance tank car design, maintenance, and repair standards. The following projects address these issues.

Quantification of Effectiveness of Localized Non-Destructive Inspection Techniques

Under the FRA regulations, tank car owners are required to employ periodic structural integrity inspections, including tank shell thickness tests and inspections of tank car welds. By limiting the required inspection to known areas of crack initiation, RSPA and FRA expect an increase in the probability of defect detection, as well as an improvement in the reliability of the inspection results and a reduction in the inspection costs. As part of this rule, five NDE methods are presently authorized: dye penetrant, radiography, magnetic particle, ultrasonic, and aided visual inspection. Other NDE methods may be used by RSPA exemption, such as acoustic emission and direct visual inspection. This rule also requires tank car repair facilities to document the sensitivity and reliability of the nondestructive evaluation methods used for the structural integrity inspections. The FRA is working with the AAR in evaluating the probability of detection (POD) for the various non-destructive inspection techniques under controlled laboratory settings. The capability of these techniques will be assessed by studying statistical trends of cracks found in repair shops using the various non-destructive inspection techniques.

Figure 4.8.2

Tank Car NDE Inspection

Acoustic Emission Inspection

With the large number of welds to be inspected on tank cars to meet the tank car structural integrity requirements, development of improved global NDE will significantly improve the probability of finding defects. Presently, acoustic emission evaluation of tank cars is providing not only information about the welds that must be inspected under the new requirements, but also any defects on any part of the tank shell. Further evaluations of acoustic emission technologies, as well as the development of other highly sensitive global NDE methods will increase the number of defects detected.

Acoustic emission tank car inspection techniques will continue to be investigated, both for periodic inspection, and inspection after damage or after involvement in accidents. Present focus will be on the source location, improved detection interpretation capability, and quantification of the effectiveness of the procedure. This effort is planned to continue through FY 2002.

Tank Car Damage Assessment/Improved Emergency Response

A tank car accident in Waverly, TN in the 1970's resulted in the death of a number of emergency responders when a tank car ruptured unexpectedly. The tank car had an undetected crack that grew over several days and resulted in the disaster. As a result, the AAR's Bureau of Explosives developed a set of guidelines for use by emergency responders. These guidelines were visual and were based on the opinions of technical experts. These emergency response guidelines—still in use—will be reviewed for adequacy, timeliness, and accuracy.

The Damage Assessment Program needs augmentation to relieve emergency responders' concerns when responding to hazardous materials accidents. Due to a lack of information, emergency responders sometimes let nature take its course, where it may have been possible to avert catastrophic conditions. These guidelines will be periodically updated when new technologies become available. The current effort is scheduled for completion in FY 2001.

Tank Car Damage Tolerance Analysis (DTA)

Because the FRA found that the continued use of stub sill tank cars poses an imminent and unacceptable threat to public safety, the FRA issued Emergency Order (EO) No. 17, in September 1992, requiring owners of stub sill tank cars to comply with the AAR Tank Car Stub Sill Inspection Program, and the AAR Tank Car Stub Sill Inspection Procedure.

Under EO17, and the AAR circular, owners must inspect the stub sill area on such cars and may not return the cars to service until all defects have been repaired and the cars are in full compliance with the Federal railroad safety regulations and the AAR Tank Car Manual. Inspection priorities were established based on characteristics discovered in other inspections and based on accumulated mileage. After an evaluation of inspection data, the railroad and tank car industries, along with FRA, NTSB recommended DTA for tank shells and structural elements and have agreed that performing DTA of each stub sill design will give tank car owners the information they require to make sound decisions on inspection and maintenance of their tank cars. The implementation of DTA requires the synthesis of structural analysis, fracture-mechanics-based crack growth predictions, and probability of detection curves for candidate inspection techniques. DTA is the aspect of an overall reliability program that ensures the continued integrity of structural components against damage accumulated during normal tank car service. The FRA is participating with the industry to develop a DTA program for use by the tank car owners, builders and users for the assurance of continued tank car structural integrity. This effort will continue through FY 2003.

Non-Destructive Evaluations to Replace Hydro Test

The presently required periodic hydrostatic testing is to be phased out because of concerns regarding the effectiveness of hydrostatic testing and the potential for structural damage resulting from this technique. It will be replaced with acceptable nondestructive evaluation methods. Of importance is the comparability of the methods, especially documented reliability and sensitivity of detection of the defect/flaw in the test specimen. This project, to develop NDEs to replace the hydro test, is planned to continue through at least FY 2002.

Remote Tank Car Inspection

Hazmat tank cars involved in an accident need to be immediately identified and located. More often than not, tank cars are derailed and are not easily identified and located within the derailment. Remote inspection is necessary for emergency response persons. The FRA will pursue R&D in this field. Advances in nanotechnology will be evaluated for application to tank car identification. This project could take several years to complete after its planned start in FY 2003.

TABLE 4.8

PLANNED TIMELINE FOR HAZARDOUS MATERIALS TRANSPORTATION PROJECTS

	FY2001	FY 2002	FY 2003	FY 2004	FY 2005
Hazmat Transportation Safety					
Hazmat Shipment Routing		●—	—	—●	
Improved Understanding of Tank Car Operating Envioronment	●—	—	—	—	—▶
Rail Transportation of RAM (SNFs-HLRW)	●—	—	—	—	—▶
Tank Car Design for 286,000 GRL	●—	—	—	—●	
Reliability Assessment Methodology	●—	—	—●		
Tank Car Safety Relief Devices	●—	—●			
Shelf Coupler Height Mismatch Issues	●—	—●			
Tank Car Closures		●—	—	—●	
Tank Car Structural Integrity					
Models for Fatigue Damage in Tank Cars	●—	—	—	—●	
Effect of Welding		●—	—	—●	
Damage in Accidents/Over-speed Impacts	●—	—	—	—	—▶
Tank Car Steels	●—	—	—	—●	
Intermodal Tank Integrity		●—	—	—	—▶
Thermal Integrity of Tank Cars			●—	—	—▶
Damage Assessment & Improved Inspection Systems					
Effectiveness of Localized NDI	●—	—	—	—	—▶
Acoustic Emission Inspection	●—	—	—●		
Tank Car Damage Assessment/Improved Emergency Response	●—●				
Tank Car DTA	●—	—	—●		
NDE to Replace Hydro Test	●—	—	—●		
Remote Tank Car Inspection			●—	—	—▶

4.9 Train Occupant Protection

This program element carries out research on structural crashworthiness and interior safety of intercity and commuter passenger rail cars and locomotives to improve the survivability of rail passengers and crewmembers in accidents. In addition, system safety and fire protection are addressed. Simulations, laboratory tests, and full-scale fire and impact tests are conducted. The goal of this research is to promote and improve the safety of intercity passenger and commuter rail services.

Why a Priority?

With the renaissance of passenger rail service in the United States, and particularly service for commuters in major metropolitan areas, the increased rail traffic alone has the potential to cause more injuries and fatalities to passengers. To handle this growth, new equipment for different services is being developed. Until recently, there were no federal or industry standards governing the safety performance of these new designs. Higher speeds also are anticipated for passenger as well as freight trains. This can also increase the severity of crew and passenger injuries.

Figure 4.9.1.

Aftermath of collision at Bourbonnais, Illinois

Several recent passenger train accidents—Gary, Indiana, in 1993, Secaucus, New Jersey, and Silver Spring, Maryland, in 1996, and Bourbonnais, Illinois, in 1999 resulted in loss of lives. The Bourbonnais accident (see Figure 4.9.1) was caused when an Amtrak train consisting of two locomotives and 11 cars struck a flatbed semi-tractor loaded with steel at a highway/rail grade crossing. Both locomotives and nine passenger cars were derailed due to the impact. As a result of the impact with the truck, a fire ensued. Of the 214 people on board the train, 11 people died and 130 were injured. These accidents emphasize the need for continued research for passenger and locomotive crashworthiness and fire safety.

A review of accidents has shown that crew safety can be improved if the crew cab space is not violated in an accident. This can be achieved by controlling the crush of the locomotives through structural redesign, and by redirecting the impacting objects where possible.

Objectives

This program element will support the FRA's Office of Safety in rulemaking activities by providing timely and comprehensive research, engineering analyses, and supporting test data; identifying risks associated with passenger rail operations; undertaking research and development activities aimed at minimizing those risks; and supporting the development of design standards and safety regulations which reduce the risk to passengers and crew members.

The five-year program will include research, testing, and implementation activities as appropriate. Full-scale impact testing is an expensive but necessary part of designing and demonstrating crashworthy equipment. This work will be supplemented with active industry partnership. The FRA has a commitment from commuter railroads for donations of used equipment and expects donations of new equipment for impact-testing purposes. This partnership will ensure that the objectives will remain in sharp focus and that the work will be carried out efficiently.

Since commuter rail service involves a wide variety of equipment and operators, it will be the focus for a joint FRA/FTA effort to improve the survivability of rail equipment in the next few years. Because the technical issues and disciplines are similar in both intercity and commuter rail services, most of the research efforts for equipment for intercity operations that are not high-speed related will be combined with those for commuter rail operations. For freight operations the main objective is to improve crew safety, in all collision scenarios including oblique raking collisions, grade crossing collisions with highway vehicles, and rear end collisions with other trains.

Expected Outcomes

The major outcomes of this program component will be:

New and enhanced federal safety standards and industry standards and recommended practices for design and construction of intercity passenger equipment, locomotives, and commuter equipment.

Design and implementation by industry of innovative new car structures which will hold down the cost and weight of safety features and minimize the effects of accidents.

A decrease in injuries and fatalities resulting from all collision scenarios.

Project Descriptions

PASSENGER EQUIPMENT

Passenger Car Crashworthiness

This project will develop safety assessment methods and assemble design data to improve the crashworthiness of passenger vehicles. Advances in mathematical modeling methods will be sought to bring the methodology up to the state-of-the-art in crash analysis, reflecting improvements in computing capabilities. A series of analyses and tests, involving different collision scenarios, are planned to evaluate the possible changes of cab and car structures to improve the safety of crew and passengers. As part of this study, several design concepts of crash energy management will be evaluated.

Secondary collisions, such as within the cab car or within the passenger car, which result in passengers or crew striking the interior of the cab or car, can also be reduced in number and severity through ergonomic design and careful planning. Passenger “compartmentalization,” seat design and fastening, seat belts, strategic placement of equipment, hand hold designs, and ride quality enhancements during rapid starts and stops are among options to be investigated.

This research includes dynamic modeling, simulations, component testing, and full-scale crash testing. Advanced analytical models that reflect the state-of-the art in crash analyses will be developed and used for the proposed work. A component test laboratory will test new structural members designed to deflect debris from collisions or absorb the crash energy in a

Figure 4.9.2.

Commuter Rail Car after 26 mph impact into a rigid wall

safe manner. These efforts will be followed by full-scale impact testing at the TTC as warranted. The purpose of these full-scale tests is to verify the simulations and to demonstrate the effectiveness of proposed remedies.

Another research project on passenger car crashworthiness will investigate the dynamics of oblique or raking impacts resulting from non-rail vehicles colliding with passenger cars and cab cars, especially at grade crossings. Emphasis will be placed on minimizing the effects of such collisions through the development and enforcement of passenger car and cab car structural standards for crashworthiness. Research on new ideas for structural members and components for improving crashworthiness, accompanied by full scale testing, is planned.

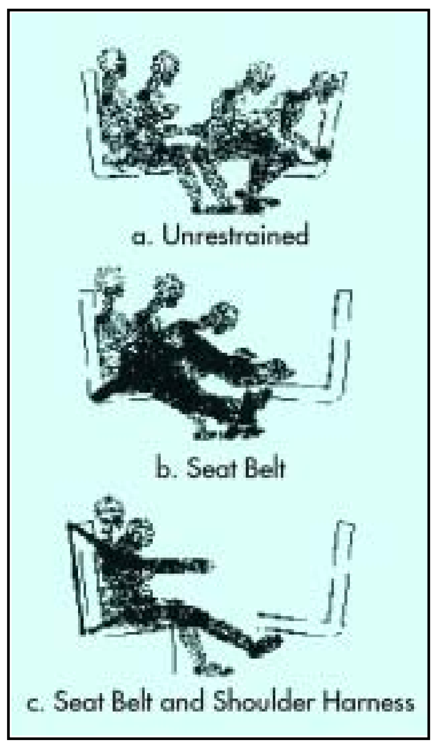
Support will be provided to the Office of Safety for continuing liaison with the APTA in the development of their safety and design practices in order to promote synergies between private and public efforts to develop safety standards. One of the new initiatives is the safety assessment of joint operation of light rail vehicles (LRV) and diesel multiple-unit (DMU) vehicles on tracks also used by freight and conventional passenger trains. This work will be conducted in cooperation with FTA and will include risk assessments and economic evaluations. (See Section 4.1 of this Plan.) This is an on-going research effort.

Emergency Preparedness

This project addresses emergency response procedures, training of system operators and emergency response organization personnel, and the provision and use of emergency equipment. A general set of recommended emergency preparedness guidelines were developed and published in 1993. The guidelines are intended to assist passenger train system operators to assess, develop, document, and improve their emergency response capabilities and to coordinate these efforts with emergency

Figure 4.9.3.

Computer Model of Unrestrained and Restrained Occupant.



response organizations. The guidelines were used as the baseline resource document in the development of the new Passenger Train Emergency Preparedness Regulations and the Passenger Equipment Safety Standard, both issued in 1999. In addition, a specific study on the issues related to safe and efficient vehicle evacuations during various emergency scenarios is planned. One goal of this study will be to determine if time-based evacuation criteria can replace existing prescriptive rules on the number and configuration of emergency exits. Other studies will be conducted, as appropriate, for emergency plans and procedures, training, emergency exits and access points, and signs. Emergency preparedness research is planned to continue through FY 2003.

Figure 4.9.4.

Instrumented Anthropomorphic Test Devices "Crash Dummies" for Development of Improved Occupant Protection Strategies in Passenger Rail Cars.

Fire Safety

This project supports the development of joint FRA/FTA federal fire safety regulations for passenger equipment in both intercity and commuter rail services. Fire safety has been identified as an important element of overall system safety for any new high-speed ground transportation technology. A major conclusion of a previous study was that the use of fire hazard and fire risk assessment supported by measurement methods based on heat release rate could provide a means to better predict real world fire behavior. Thus, a project was initiated with National Institute of Standards and Technology (NIST) to demonstrate the practicality and effectiveness of new generation test methods and hazard analysis techniques when applied to passenger rail vehicle fire safety. To date, typical system components and materials have been identified and evaluated in bench-scale and full-scale heat release rate tests. A baseline analysis of the overall system fire hazard is planned. Changes in materials and vehicle design on the baseline fire hazard will then be analyzed. This research is planned to continue for at least three more years.

Crashworthy Self-Propelled Commuter Rail Vehicles

FRA, in cooperation with FTA, proposes to undertake a program to develop crashworthy self-propelled commuter railroad vehicles that could safely share track with freight and intercity passenger trains.

Commuter railroads and transit authorities anticipate continued growth in the demand for their services, and at the same time they face constraints in the availability of capital to construct new systems. Consequently, they view the use of existing railroad tracks as a key element of their strategy to initiate new commuter rail services with the lowest possible capital outlay. To keep capital and operating costs for rolling stock low, commuter railroads and transit authorities in some instances are considering service with self-propelled DMU cars, and in other instances are considering use of diesel or electric LRVs.

From the point of view of the FRA, the principal drawback to these strategies is that LRVs and some new designs of DMU cars lack the physical strength to provide crashworthiness should they collide with conventional railroad equipment sharing the same tracks. FRA's Office of Safety has informed the commuter railroads and commuter authorities of these concerns. APTA and its members, in turn, have requested FRA and FTA to assist them by sponsoring the development of crashworthy self-propelled commuter rail vehicles that can be safely deployed on tracks used by freight and intercity passenger railroads.

LOCOMOTIVE SAFETY/CRASHWORTHINESS

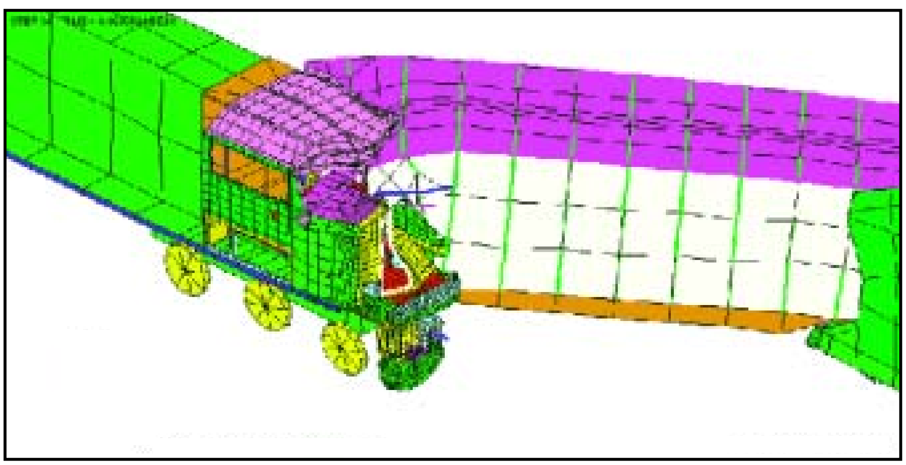
Locomotive Crashworthiness

The project began with finite element modeling (FEM) of the current generation of freight locomotives, which conform to AAR Standard S-580 for locomotive cab configuration, for use with different collision scenarios. These scenarios include oblique or raking collisions with hi-rail or highway vehicles and shifted loads on passing freight trains. Head-on and rear-end collisions with other locomotives and cab cars will also be considered. The collision modeling will investigate override, crushing of the structure, locomotive cab penetration, and locomotive cab impact pulse. Secondary collisions resulting in the impact of cab occupants with interior appurtenances will be studied. The integrity of cab attachments will be assessed. Considerable modeling work has already been done on some collision scenarios and efforts will build on that experience.

Use of anti-climbers and collision posts has done much to reduce fatalities. Equipment performance in recent rear-end and head-on collisions has demonstrated that such design changes can produce positive results. Further research is planned to conceptualize and develop proposed prototype modifications to the locomotive structures followed by laboratory testing. These modifications may be made to the corner or collision posts, anti-override members, or other end structures. Computer modeling of collisions would be carried out, and full-scale

Figure 4.9.5.

Locomotive Collision with Hopper Car



collision testing will be conducted as appropriate. Up to five different collision scenarios are envisaged. In each case the proposed collision will be modeled and the results compared with the collision outcome. This may entail a locomotive-to-highway vehicle impact or a locomotive-to-locomotive crash. The full-scale test verification would be expected to provide sufficient confidence in the modeling to proceed with the evaluation of alternate concepts without testing every concept. A full-scale static test fixture for testing alternate crash structures to failure has been designed and is being constructed.

Liaison with locomotive builders will be maintained for the purpose of information exchange, and partnering in the proposed testing. Proposed performance and design/test requirements for rulemaking purposes will be prepared. These requirements will be presented to a joint FRA-industry group such as RSAC for consideration and adoption.

Fuel Tank Integrity

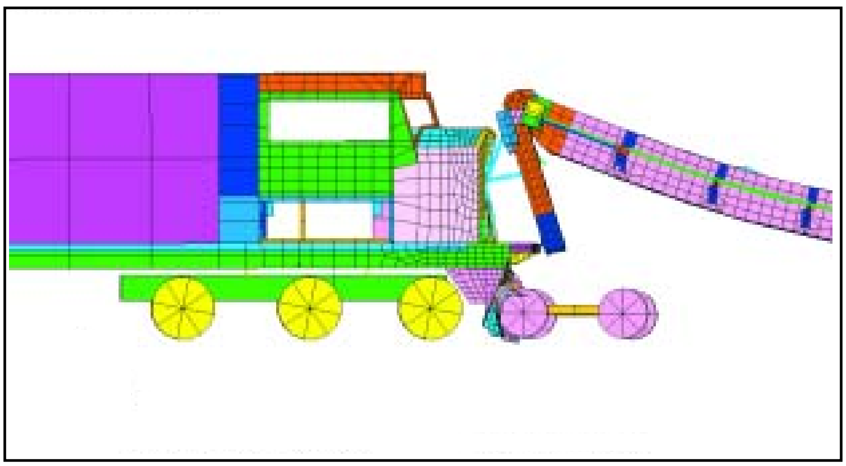
Another project is investigating the crashworthiness of locomotive fuel tanks. Research has indicated that the current design, recently adopted by the railroads, is an improvement. However, a few recent accidents have resulted in puncture of the fuel tank. Accidents will be tracked for fuel tank integrity on a continuing basis. Research may include testing of fuel tank integrity to validate the analytical studies. Compartmentalization of fuel tanks may also be studied for possible adoption as a standard. The fuel tank integrity work is planned to be ongoing through FY 2005. At that time, a determination to revise the design requirements can be made and the rules modified.

Crew Safety

Emergency egress from locomotive cabs could make them a safer work environment. Research on locomotive cabs egress and passenger car emergency egress in the event of a derailment or accident will be undertaken. The objective will be to provide for adequate egress for crews and passengers

Figure 4.9.6.

Locomotive Collision with Intermodal Car

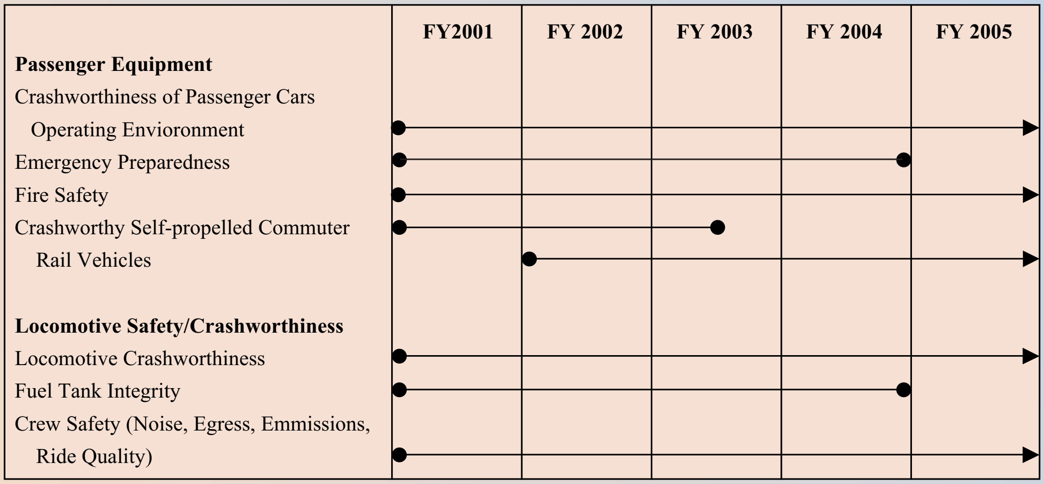


for any reasonable conditions that may occur in an accident. Improving egress from locomotive cabs may include door/window redesign and alternate exits such as emergency hatches.

Overall locomotive crew safety also includes cab-working conditions. Research is being conducted to identify the sources of noise in the locomotive cab that may be harmful to the crew's hearing. Reducing entry of fumes from diesel exhaust into the cab will also be investigated. Ride quality and vibration are another area of concern. Research on ride quality is planned for FY 2002. Rulemaking support is also provided to the FRA Office of Safety for locomotive cab temperature, noise, vibration, and sanitation. Crew safety improvements are ongoing and work is planned to continue at least through FY 2005, at which time the focus may shift to the use of additional new technologies to improve crew safety.

TABLE 4.9

PLANNED TIMELINE FOR TRAIN OCCUPANT PROTECTION PROJECTS



4.10 R&D Facilities and Equipment

Projects in this element are for acquiring, upgrading, and maintaining FRA-owned facilities and equipment required to accomplish the entire spectrum of railroad research objectives. This activity supports the goal in the U.S. Department of Transportation Research and Development Plan for DOT to have a "world-class transportation R&D capability." FRA's R&D facilities and equipment includes the 52-square mile Transportation Technology Center (TTC) (Figure 4.10.1) near Pueblo, Colorado; two research and test cars, and several portable measurement devices to support field testing requirements.

Figure 4.10.1

Transportation Technology Center

TTC serves as the Nation's railroad research center. It includes 11 major buildings, 50 miles of track, and a variety of locomotives, cars, and laboratory testing equipment. The center, which employs about 280 people, is operated under contract by TTCI, a subsidiary of the AAR. TTC is used by the FRA, other government agencies, the railroad industry, individual railroads, transit operators, suppliers, and foreign organizations—with each project funded by the organization that requests the work. A wide range of locomotives, cars, track components, and components for freight, passenger, transit, and high-speed rail operations are tested at the site.

A small sample of TTC's facilities and activities: TTC's 13.6-mile high speed test track served as a proving ground for Amtrak's Acela trains and for the experimental non-electric high speed locomotive being developed under the Next Generation High Speed Rail Technology Demonstration Program; a freight train running on the 2.7-mile High Tonnage Loop generates tonnage and wear on track and equipment components to help identify methods and materials for withstanding heavier freight car axle loads; rail and wheel defects are investigated in the metallurgical laboratory; the hazardous materials training school teaches emergency response to accidents involving railroad shipments of toxic liquids and compressed gases, with full-scale practice accident sites—and real fire.

In addition to the fixed facilities at TTC, the FRA owns and operates a pair of research rail cars to support the track research program. These rolling laboratories are, to a great extent, products of FRA R&D; they contain instrumentation and data processing techniques specially designed for conducting railroad research within the railroad environment.

In 2000, FRA acquired a retired passenger car from Amtrak and had it refurbished and equipped for research purposes. This car, T-16 (Figure 4.10.2), is now capable of making track measurements at speeds up to 165mph. It can measure track geometry, ride quality, rail profile, and wheel/rail force parameters based on FRA Track Safety Standards for high-speed operations. It also serves as a track research instrumentation platform. That is, in addition to making track measurements, it also serves as a means for developing and testing the instrumentation, software, and equipment which produces the measurements and processes the recorded data. While certain instrumentation remains permanently in place on T-16, others are installed and removed to meet the needs of particular tests and research efforts.

Figure 4.10.2

The New FRA High Speed Track Research Car: T-16

R&D's other research car, T-6, serves as host to the Gage Restraint Measurement System (GRMS), which measures the track's ability to maintain gage to preclude a wide-gage derailment. This product of FRA R&D is a performance-based inspection system that has been widely accepted and applied by the railroad industry, and has recently been incorporated in the FRA track safety standards. The main GRMS component - the split axle wheelset, is shown in Figure 4.10.3. This special wheelset is installed on a freight car coupled to T-6. Instrumentation aboard T-6 collects and processes the data and controls the lateral load applied by the split axle wheelset.

The FRA has a number of pieces of portable specialized equipment to ensure quick response capability with respect to field-testing and related instrumentation when necessary. Examples of this unique and specialized equipment in the current inventory include the Ride Quality Measurement System, shown in Figure 4.10.3, to measure the vertical and lateral rail vehicle acceleration; the Lightweight Track Loading Fixture, shown in Figure 4.10.4, which is a manually operated track inspection tool to test the lateral strength of crossties and fastening systems, and complementing the GRMS with spot checking as required; and the Direct Wheel Load Measurement System, shown in Figure 4.10.5, to measure static lean of railcars which is a required data for evaluating waiver requests for higher cant deficiency operations.

Through the combination of FRA-owned equipment and contractor technical support services, the FRA has been able to maintain the capability to independently evaluate track and structure integrity through quick-response instrumentation, test support, and materials testing. The FRA also has specialized portable equipment to provide a quick response capability, and for cases where full-sized cars are not practical or necessary.

Figure 4.10.3

Split Axle Gage Restraint Measurement System

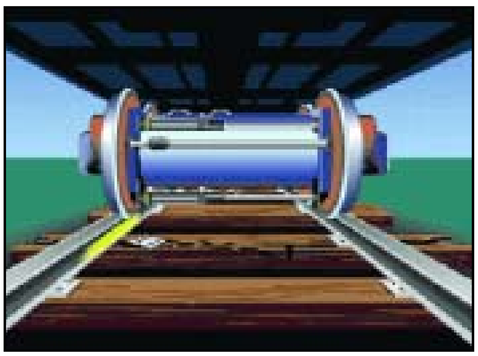


Figure 4.10.4

Lightweight Track Loading Fixture

Figure 4.10.5

Portable Ride Quality Measurement System

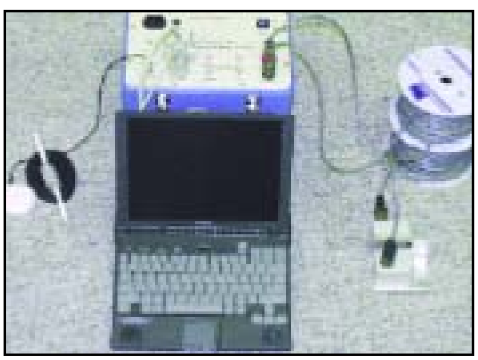


Figure 4.10.6

Direct Wheel Load Measurement System

Objectives

The objectives of this element are to provide the FRA with the type and quality of facilities and equipment needed to meet its research mission. These objectives include:

- Maintaining the FRA capability to independently evaluate railroad equipment and infrastructure integrity through quick response instrumentation, test support, and materials testing at a minimum cost.
- Advancing track defect detection technologies by providing specialized railcars to serve as a testbed for the evaluation of research products and prototypes.

- Enabling the infrastructure at TTC to accommodate the testing and evaluation of Intelligent Railroad Systems technologies.

Expected Outcomes

- Responsiveness to FRA mission requirements with respect to track safety evaluations.
- Expedited wide spread deployment of new technologies such as GRMS that have the potential for significant improvement in track safety.
- A test platform for "smart technologies" for track safety evaluations which add to current safety exceptions reporting, and be predictive and prescriptive in scheduling and specifying the required corrective actions, simultaneously benefiting safety and economy.
- Meet FRA's needs for safety-critical field test data relative to aspects of both high-speed and heavy-axle freight railcars.
- Maintain a railroad research facility that can be used to evaluate track and vehicle performance based on safety standards and performance guidelines, and perpetuate future improvements.

Project Descriptions

Transportation Technology Center (TTC)

TTC is now over thirty years old. Many elements, such as building roofs, have reached or are nearing the end of their useful life, and some equipment is becoming obsolete and is uneconomic to upgrade. These items must be replaced. Changes in building codes, regulations, technology, and testing demands, also dictate improvements.

While the contractor operating TTC for the FRA takes responsibility for a substantial share of maintenance and capital investment, the Federal Government, as owner of the facility and landlord, also bears responsibility for investments and improvements needed to maintain state-of-the-art research capabilities, to comply with changing safety and environmental regulations and practices, and to ensure that TTC can meet Government research requirements. This sharing of responsibility is an important part of the agreement between the FRA and TTCI. The following improvements will permit the FRA to fulfill its responsibility for TTC and will help TTC to remain a state-of-the-art research facility:

- Upgrade of the water distribution system for fire protection and domestic water supply.
- A site master plan to properly tie future infrastructure plans with current facilities, utilities, and available land area.
- Mitigation of environmental deficiencies, including freon in older air conditioning systems.
- Roof and exterior restorations on four major buildings.
- Additional telephone and communications lines to accommodate expected demand and to meet current technological standards.
- Completion of the vehicle tracking system, begun in 2000, to provide better information on the location of vehicles to the TTC's Operations Center and to serve as a test bed for train control research. (See Section 4.6 in this Plan).
- A facility for maintaining high-speed trains to support the high-speed test track, which became operational in 1999. This facility would require a wheel truing machine, a drop table, and overhead cranes.

- A fire sprinkler system for the main office building.
- Safety appliances in several buildings to meet changing safety code requirements.
- Resurfacing and other improvements to roads and parking areas.
- Electrical system upgrades in several areas, including the Transit Test Track and Railroad Test Track.

Track Research Car T-16

With the initiation of higher speed passenger train service between Washington and Boston and the issuance of track safety standards for speeds up to 200 mph, accurate measurements requiring sophisticated instrumentation have become essential for evaluating track-train system performance. FRA's research car, T-16 provides this capability and will permit further refinement in performance measures at higher speeds. T-16 is also needed to examine future high-speed corridors and routes intended for upgrading to higher maximum speeds, and to monitor and perform research at the TTC's high-speed test track, and on the Northeast Corridor. In addition to regular maintenance, T-16 will need instrumentation upgrades to fulfill its high- speed mission.

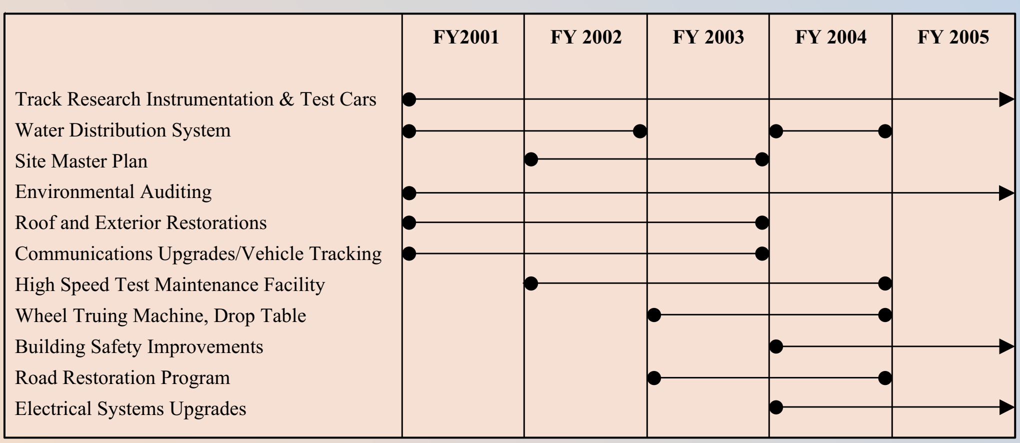
T-16 also serves more broadly for improving track inspection for conventional passenger and freight operations. Of the present 55 track-related cause codes in the FRA's Accident/Incident database, analysis indicates that 22 of these causes are amenable to detection using five currently available automated inspection techniques, with the remaining 33 accident causes currently requiring visual/physical inspections. Further analysis indicates that with the addition of new technologies such as the Vertical Modulus Measurement System and the Ground Penetrating Radar (GPR), automated inspection for 26 of the remaining 33 track accident causes may be possible. T-16 will permit the development and the integration of these technologies to improve track safety inspection.

Track Research Car T-6

The GRMS is currently deployed with the T-6 railcar, an almost 40-year old US Army surplus car that is increasingly difficult and expensive to maintain. The Office of R&D has planned to upgrade the aging T-6 to provide a self-propelled platform and to update the data collection, location identification, and communication systems. The GRMS (split axle) truck will be reconditioned and retrofitted to the new platform to minimize impact on system availability and to control costs.

TABLE 4.10

PLANNED TIMELINE FOR R&D FACILITIES AND EQUIPMENT PROJECTS



chapter 5.0

Next Generation High-Speed Rail Technology Demonstration Program

The Next Generation High-Speed Rail Technology Demonstration Program ("Next Generation Program") seeks to demonstrate technology that will facilitate the incremental development of high-speed rail (HSR) passenger service that has air or road competitive door-to-door trip times between major city pairs and reliable, high quality, cost-effective service.

Mobility between major urban areas is a vital component of American society. However, highways and airport facilities on vital intercity corridors around the nation are suffering unacceptable congestion as travel demand grows. Construction of new limited access highways can cost $40 million per lane mile, and airport expansion is often not feasible because of surrounding development. High-speed ground transportation systems such as those built in Europe and Japan provide superb service quality, but implementation of such systems in the United States has been prevented by high costs and the difficulties associated with acquiring new rights-of-way.

Existing railroad routes provide an attractive, practical alternative to meet present and future mobility demands in corridors connecting major urban areas up to 400 miles apart. Presently, technology is available to operate trains at speeds of 110-125 miles per hour, and potentially up to 150 miles per hour on existing infrastructure—as on Amtrak's Northeast Corridor. These technologies can provide competitive trip times on the order of three hours in selected corridors.

The Congress, in the Swift Rail Development Act of 1994, found the development of suitable technologies for the implementation of high-speed rail to be in the national interest and authorized the FRA to undertake such technology development. The Next Generation Program was established to undertake that challenge. Activities are underway in program elements where development and demonstration activities have a high potential return on investment when upgrade programs are implemented.

The Next Generation Program includes the following four elements:

1. **Positive Train Control** - Demonstrations of systems suited to maximizing the capacity of railroads to carry a mix of high-speed passenger, commuter, and freight trains with minimal risk of collision and at considerably lower cost than conventional railroad signal and control systems.
2. **High-Speed Non-Electric Locomotive** - Demonstration of a locomotive to achieve the speed and acceleration capability of electric trains without the expensive infrastructure of railroad electrification.
3. H**igh-Speed Grade Crossing Protection** - Development and demonstrations, including barrier systems and innovative warning devices, to provide nearly the same security as grade separations but at much lower cost.
4. **Track and Structures Technology** - Demonstrations of cost effectively increasing route capacity and/or improving performance of the infrastructure on existing corridors to be sufficiently robust to permit shared heavy freight and high-speed passenger use with satisfactory ride quality.

The Next Generation Program is built around these concepts to make available the new technology and devices that are particularly suited to applications for near-term implementation of high-speed rail by the states. Federal sponsorship of the program is necessary because no single State represents a large enough market to justify the necessary technology development efforts. The railroad supply industry perceives the market to be too small to independently fund technology development costs until several corridor upgrades are underway to substantiate a market of reasonable size.

The Next Generation Program is based on partnerships with suppliers of technology, railroads, and State governments. By working with State and railroad partners, a real-world environment is provided for the application of these technologies, preparing the way for a smooth introduction when States are ready to implement their systems. States that are now implementing incremental upgrade programs are targeting service speeds of 110 to 125 miles per hour for the near future, primarily on existing track used for freight operations.

The Next Generation Program first received significant funding in FY 1995. During the past six years, significant advances were accomplished in each of the major program areas, as separate technology and demonstration pursuits. For the next five years, the strategic direction of the program will be to complete the major projects begun in each of the four program elements, and upgrade demonstration corridors on an entire-corridor basis to validate the concept that high quality intercity rail passenger service can produce the revenue needed to sustain its own operations. High-speed rail service can be realized only if one or more corridors achieve short trip times with safe, attractive, and reliable service on a sustained, daily basis.

The program element descriptions are based on actual FY 2001 and 2002 appropriations and the President's FY 2003 Budget Request. Activities described as occurring in Fiscal Years 2004 and 2005 are contingent upon funds being appropriated to carry them out.

5.1 Positive Train Control Demonstrations

Train control systems are mandated by the FRA for all track where any train will operate at 80 miles per hour or faster. This mandate means that economical, effective train control systems are essential for the success of high-speed rail development.

At present, Amtrak's Northeast Corridor, the New York State Empire Corridor, and the Richmond/Washington section of the developing southeast high-speed corridor are equipped with train control systems that permit or could permit high-speed operation. The systems presently installed are based on wayside signal information inductively coupled into the running rails and read by a receiver aboard each locomotive. The onboard unit repeats the wayside signal indications inside the locomotive cab and is configured so that speed in excess of the permitted speed will result in an automatic application of the train brakes. These systems work very well and have been proven over many years service. However, the existing systems are limited in the number of speed indications presented to the engineer (usually 4), most do not enforce civil speed restrictions, and they require initial wiring and subsequent maintenance of control circuits to the rails of each track block, and are relatively expensive.

The digital data radio communications systems, wayside and onboard computers, and automatic positioning systems that are key elements of the Intelligent Railroad Systems described in Chapter 2 offer the potential for much more flexible control approaches at significantly reduced cost when compared with existing hard-wired technologies.

Why a Priority?

Installation of any train control system on a developing high-speed rail corridor and its locomotives is a major potential expense, hence a determinant of the feasibility of any high-speed upgrade. Compounding the potential expense is the requirement that all locomotives operating on such territory also be equipped, including all freight trains operating there. Since the locomotives of the major freight railroads are highly itinerant, either all freight locomotives of each freight carrier in the territory must be equipped or a dedicated equipped fleet of freight locomotives must be established to permit high-speed passenger operations on a corridor. The cost of equipping freight locomotives becomes a major source of contention between passenger and freight railroads if the train control system is required only to permit high-speed passenger service.

Objectives

The objective of this program element is to complete the development of and to demonstrate advanced train control systems, proven to be safe and suitable for high-speed operations, which would be available to States and their partners at a cost significantly lower than conventional hard-wired signal systems. A major technical objective is to demonstrate "flexible block" operations wherein the train control system will permit trains to be operated at the minimum headways consistent with safety, without regard to fixed wayside signal locations. This will increase available route capacity for any given track layout, thereby making additional capacity available for the operation of high-speed trains.

Expected Outcomes

This program element will result in validated, cost-effective technologies—coordinated with the freight railroad industry—which States and their railroad partners will be able to select and implement on emerging high-speed corridors. The effectiveness of the prospective train control systems must ultimately be demonstrated over total corridor lengths; dealing not only with relatively simple, uncongested rural operations, but also with urban rail terminal areas where operations are frequent, complex, and compete for communications spectrum with thousands of other radio transmitters both on and off the railroad property.

Technology Demonstration Project Descriptions

Incremental Train Control System (ITCS) Project

ITCS is being installed on a segment of the Amtrak-owned portion of the Detroit-Chicago high-speed corridor under FRA sponsorship and in partnership with the State of Michigan, Amtrak, Norfolk Southern, and General Electric Transportation Systems Global Signaling.

This system monitors the status of the railroad through the electronics of the existing wayside signal system and radios this status information to computers aboard each locomotive. The onboard computer compares the received status information with its onboard database and determines and informs the engineer of permitted speeds and limits of operation. The onboard system stops the train if unsafe operation is attempted. The ITCS approach is more basic than other HSPTC approaches in that it does not require a central control computer; but it thereby remains dependent on fixed wayside signal blocks and would not permit flexible block operation.

ITCS has been installed on the entire 70-mile demonstration territory, and safety verification is underway. Accomplishing revenue service at more than 79 mph was achieved in 2001; full safety verification and validation is targeted for FY 2002, permitting speeds up to 110 mph.

North American Joint Positive Train Control Program (NAJPTC)

A comprehensive approach is underway for development and demonstration in the high-speed PTC project on a portion of the Chicago/St. Louis high-speed corridor owned by the Union Pacific Railroad. This system is being developed under FRA sponsorship in partnership with the State of Illinois, Amtrak, and the AAR, and Transportation Technology Center, Inc. administers the program for the partners. The team of Arinc and Canac is serving as the System Engineer.

A system design and integration contract was awarded in June 2000, to the team of Lockheed Martin, Wabtec, Union Switch and Signal, and Parsons Brinckerhoff, to design and install the demonstration system in Illinois. The project is committed to installation and full safety validation so that Illinois and Amtrak can begin revenue high-speed passenger service in 2003.

Amtrak and Union Pacific trains operating in this system will automatically determine their location and report it periodically by data radio to the Union Pacific control center in Omaha, Nebraska. The control center computer, under dispatcher instructions, will determine safe and effective movements for each train and instruct the onboard computer by return data radio link as to its limits of operating authority. The onboard system will inform the engineer of permitted speeds and limits of permitted operation, then oversee operation of the train and automatically bring the train to a stop if unsafe operation is attempted. This system is intended ultimately to be capable of “flexible block” operation, in which minimum safe headways of trains will be maintained without the need for wayside signals, thereby maximizing the number of trains which can be carried over any given route.

Alaska Railroad Positive Train Control Project

For the past several years the U.S. Congress, has provided funds to FRA for a PTC project on the entire 686-mile Alaska Railroad; which, even though not a high-speed railroad, operates passenger, freight, and intermodal trains between Seward, Anchorage, and Fairbanks over difficult terrain in harsh weather conditions. The PTC system will supplant the railroad’s current system of transmitting movement authorities by voice radio from dispatchers to train crews and track forces—the Alaska Railroad has no signals installed along its tracks. Phase I was the design, development, and installation of a computer-aided dispatching system by General Electric Transportation Systems Global Signaling for the railroad’s dispatching center in Anchorage. Phase II was the installation of a digital data communications system along the entire railroad to supplement the voice radio communications system. Phases I and II are now complete. In phase III, the design and development of the locomotive on-board computers and track forces terminals was underway, but work has been terminated due to a contract disagreement with the vendor.

Advanced Railroad Communications System Testing

FRA has initiated an advanced railroad radio network demonstration project in the Pacific Northwest, applying digital transmission of voice communications and data between trains and dispatchers. The project is funded through the State of Oregon to the Union Pacific and Burlington Northern Santa Fe Railroads. The advanced communications network being demonstrated will provide more efficient use of existing radio spectrum while laying the ground work for future positive train control system implementation. The project is demonstrating a "trunked" radio network in the Portland metropolitan area. With this system, users are not assigned a specific individual radio channel but are flexibly routed to one of a group of channels shared with many other users. A computer control system monitors communications demand and assigns the available channels to users in priority order. The seven channels used by the "trunked" system can serve as many users as might be served by 10 to 15 regular channels, depending on the timing of communications demand.

The project also involves installing a radio network the full length of the rail corridor between Eugene, Oregon, and Vancouver, British Columbia. This network uses digital transmission techniques designated APCO25 (American Public Safety Communications Officers Project 25), developed for the public safety radio dispatch services. Equipping Amtrak trains on the route with the new transmitters and with NDGPS-based location systems will test the characteristics of this new digital network. Each train will transmit its location using both old and new communications methods, and the effectiveness of each method will be recorded. The data transmitted will also be made available to a new passenger information system with displays on station platforms, providing waiting passengers with current train location information. The new digital transmission method will ultimately be applied to transmit train control messages. FRA plans to monitor and evaluate this project through FY 2004.

FRA is also supporting efforts to establish a railroad communications testing facility at the TTC. Initial efforts include testing and evaluation of a European digital radio technology known as GSM-R (Global System for Mobile - Railroad) cooperatively with the AAR at the TTC in FY2001 and 2002. European railroads and suppliers developed this technology. for application to communications-based train control systems.

5.2 High-Speed Non-Electric Locomotive Technology

This program element develops and demonstrates a fossil-fuel turbine-powered locomotive suitable for high-speed passenger rail operations. The criteria for success includes high acceleration rates, reasonable power levels, low forces applied to the track, high reliability, and economy of purchase, operation, and maintenance. Only increasing available power and reducing the weight of the locomotive in comparison with existing diesel-electric designs now employed for passenger service at speeds up to 100 miles per hour can achieve success.

Why a Priority?

Emerging high-speed services will succeed only if trip times are reliably low. Reliable low trip times can be accomplished only if average trip speeds are kept high by minimizing acceleration and braking times, thus sustaining high-speed for most of the trip. Recovery must be very rapid from any operational slowdown, or average time suffers. Schedules typically have little or no reserve so that each minute lost en route is likely to become one minute late on arrival. Today's diesel-electric passenger locomotives are derivatives of freight designs; consequently, they are relatively heavy and their diesel-electric power plants rapidly lose the ability for additional acceleration at speeds above 80 miles per hour. This stretches acceleration times and virtually precludes speeds over 100 miles per hour. Suitable motive power is essential for developing corridors to maintain any prospect of high-speed service.

Emerging high-speed corridors are not presently electrified, and are operating limited numbers of passenger trains on today's longer schedules. Electrification has very attractive service characteristics but represents an unattainable initial capital investment for most states that face an undeveloped rail market and severe budget constraints. Self-contained motive power that provides comparable service levels without requiring the initial capital expense of electrification, is highly sought-after by the States to permit incremental service upgrades and to build a customer base. Electrification may then be reconsidered to deliver efficiency and environmental benefits when substantial demand has been built in any given corridor.

Objectives

The objective of this program element is to develop and demonstrate a fossil-fuel self-contained locomotive which matches or exceeds the acceleration, and matches or improves upon the track loading characteristics of an AEM-7 electric locomotive as now employed on Amtrak's Northeast Corridor.

Expected Outcomes

The availability of demonstrated, cost-effective high-performance locomotive technology is an essential precursor for high-speed service on the emerging high-speed corridors. The expected outcome of this program element is a fleet of such locomotives demonstrating high acceleration, high-speed, and reliable service on one or more corridors.

Technology Demonstration Project Descriptions

High-Speed Non-Electric Locomotive

The FRA has entered into a cooperative agreement with Bombardier, Inc. to develop and demonstrate a high-speed gas turbine-powered locomotive. The locomotive is now being tested at the TTC, after which demonstrations will be conducted on corridors throughout the United States. The locomotive is compatible with Acela Express passenger cars. Demonstrations and evaluations are planned to take place through FY 2002 and 2003.

Figure 5.2.1.

High-Speed Turbine-Powered Locomotive

Passenger Locomotive Prototype

Advanced Locomotive Propulsion System (ALPS)

This project, undertaken by the University of Texas Center for Electromechanics and Honeywell International, will develop and demonstrate an energy-storage flywheel device to be used with the high-speed non-electric locomotive. The flywheel will permit a locomotive with only one prime-mover system to accelerate for a period up to several minutes—as if it had two prime-mover units. This additional "boost power" is a key to the necessary high acceleration rates; it improves energy efficiency by storing braking energy, and it permits "load leveling" for turbine prime-movers, which can substantially improve their operating efficiency while lowering their life cycle maintenance costs. The turbine-driven, 3-megawatt generator and the full-scale energy storage flywheel are being assembled. The generator will be mated to a Honeywell turbine and mounted on a skid for installation in the Bombardier demonstration locomotive. The energy storage flywheel will be mounted in an auxiliary car body for subsequent testing with the locomotive.

Turboliner Upgrade and Refurbishment

To continue the development process begun with the upgrade of one Rohr Turboliner and improve performance even further, the FRA and New York State Department of Transportation began a project in 1996 to upgrade six additional Rohr Turboliner train sets. The train sets will have advanced turbine engines to permit service at speeds up to 125 miles per hour and with enhanced acceleration capability. The train sets, upgraded by Super Steel Schenectady Inc., are designated the RTL-3 and should go into demonstration service in 2002. FRA plans to monitor and evaluate their performance through 2003.

5.3 High-Speed Grade Crossing Protection

This program element supports and evaluates grade crossing safety demonstration projects[1]. Funding to demonstrate new concepts for improving safety at grade crossings is provided through the Next Generation program, the Transportation Research Board IDEA Program (see Appendix B), and Section 1103 of TEA-21. Current projects for which support is being provided include: the Connecticut four-quadrant gate with obstacle detection system, other four-quadrant gate projects in Florida, Indiana, and North Carolina; North Carolina's Sealed Corridor Initiative; the Vehicle Proximity Alert System; and the locked gate at private crossings in New York and Oregon. Information on the latter two projects is provided in Section 4.7.

Technology Demonstration Project Descriptions

Four-Quadrant Gate with Obstruction Detection

The state of Connecticut received a grant to demonstrate a four-quadrant gate with obstruction detection, notification to the locomotive engineer, and positive train control system in adequate time for the train to be stopped. As a train enters the approach circuit, the grade crossing warning systems are activated and the four gates are lowered simultaneously. Inductive loops within the gated area can detect vehicles weighing 500 pounds or more, and if detected the appropriate exit gate remains up or ascends to allow the vehicle to exit. Concurrently, a signal is sent to the locomotive engineer that a brake application should be made. Should the vehicle

[1] FRA grade crossing research and development projects are described in Section 4.7 of this Plan, and human factors projects related to grade crossings are described in Section 4.2

exit the crossing area prior to the train's arrival, a clearance signal is sent to the engineer and the train can resume speed; but, if not, the train can be safely brought to a stop. This system will be installed at seven additional locations on the NEC. The actual demonstration is complete, but data collection continues at the site.

Michigan ITCS Demonstration

This demonstration includes the upgrade of 57 public grade crossings to provide constant warning times and improvement or elimination of 21 private grade crossings.

North Carolina's "Sealed Corridor" Initiative

The Sealed Corridor Initiative addresses the safety needs of each crossing on a case-by-case basis along a 92-mile segment between Charlotte and Greensboro on North Carolina's high-speed rail corridor. FRA grants are providing the funding for the installation of innovative highway-rail crossing devices such as median barriers, articulated gates, long gate arms, four-quadrant gates at crossings, and closing of redundant crossings. Other elements of the initiative include traffic separation studies to consolidate crossings, video enforcement, video monitoring, data collection, studies of driver behavior and the demographics of violators, innovative warning devices, and use of improved signs at private crossings. A program evaluation conducted by FRA in calendar year 2001 as requested by Congress shows that five lives have already been saved by the enhanced systems installed on this corridor. The FRA will continue to monitor this project and work with the North Carolina Department of Transportation to develop a methodology to be used in other developing high-speed rail corridors.

Figure 5.3.1.

Four Quadrant Gates on the North Carolina Sealed Corridor

5.4 High-Speed Track and Stuctures Technology

First introduced in 1997, this program element addresses issues associated with route capacity limitations of existing corridor infrastructure by seeking out and demonstrating innovative, more cost-effective construction methods to construct new track and structures. It also seeks out and demonstrates components suitable simultaneously for comfortable, high-speed passenger operations and durable enough for frequent, heavy axle load freight operations.

Why a Priority?

Since deregulation, the freight railroad industry in the United States has undergone a renaissance. This means that rail corridors that once had excess capacity are now at operating limits and are suffering marked congestion. Introduction of new high-speed services on such corridors will be accomplished only if existing capacity can be cost-effectively increased, either by higher speeds, other improvements in operating methods, or by construction of new infrastructure. Each of these mitigation methods can represent a substantial part of the needed investment for public entities proposing to implement high-speed service. In the component arena, infrastructure elements must be capable of meeting the dual criteria imposed by two very different types of service.

Objectives

This program element demonstrates cost-effective methods and technologies for creating new route capacity on existing corridors, and identifying and demonstrating components suitable for the demands of both high-speed passenger service and heavy freight service operating on the same track structures. High-speed passenger service requires track and structures finely tuned and carefully maintained to exacting tolerances. Heavy freight service requires extremely strong and durable components to withstand high impact loads and rapid wear.

Expected Outcomes

This program element will provide validated new technology to permit States and their partners to afford infrastructure investments for adequate route capacity, with satisfactory performance, to implement high-speed passenger service on already-congested freight corridors.

Technology Demonstration Project Descriptions

Infrastructure Upgrade on the Pacific Northwest Corridor

Track, structures, and grade crossings will be upgraded to permit higher speed operations between Eugene, Oregon, and Vancouver, Washington.

Subgrade Mitigation Techniques

This project will demonstrate advanced techniques to resolve longstanding subgrade problems that degrade ride quality and threaten the operational safety of high-speed track, and which cause excessive maintenance requirements and expense. Innovative mitigation techniques were applied to a test zone on the Massachusetts Bay Transit Authority (MBTA) near Boston in early 2000, an assessment is currently underway.

Improved Track Performance at Reduced Maintenance Expense Using Advanced Inspection Data

This project will demonstrate a technique for applying precision maintenance methods based on quantified track gauge strength information newly available from Gage Restraint Measurement Systems now being deployed by FRA and railroads. The new methods are targeted at permitting high-speed passenger operation and heavy axle-load freight operation on existing track at reasonable maintenance expense.

Increase Operating Speeds while Improving Ride Quality Over Bridges

Locations where the track structural stiffness changes; such as highway grade crossings and railroad bridge ends, are notorious as chronic sources of track-train impact forces, poor ride quality—sometimes verging on safety hazards—and requiring excessive maintenance. This project will develop techniques to improve ride quality and increase permissible operating speed over bridges.

TABLE 5.1

PLANNED TIMELINE FOR NEXT GENERATION HIGH-SPEED RAIL TECHNOLOGY DEMONSTRATION PROJECT

	FY2001	FY 2002	FY 2003	FY 2004	FY 2005
Positive Train Control Systems					
Incremental Train Control System Project	●—	—	—●		
North American Joint Positive Train Control Program	●—	—	—	—●	
Alaska Railroad PTC Project	●—	—	—	—	—▶
Advanced Railroad Communications System Testing	●—	—	—	—	—▶
Development of Non-Electric Locomotives					
High-Speed Non-Electric Locomotive	●—	—	—●		
Advanced Locomotive Propulsion System	●—	—	—	—●	
Turboliner Upgrade and Refurbishment	●—	—●			
High-Speed Grade Crossing Protection					
Four-Quadrant Gate with Obstruction Detection	●—	—	—	—●	
Michigan ITCS Demonstration	●—	—	—●		
North Carolina Sealed Corridor	●—	—	—●		
Track and Structures Technology					
Infrastructure Upgrade on the Pacific Northwest Corridor	●—	—	—●		
Subgrade Mitigation Techniques	●—	—	—●		
Improved Track Perfornamce at Reduced Maintenance Expense	●—	—	—	—	—▶
Increased Operating Speed while Improving Ride Quality Over Bridges	●—	—	—●		

chapter 6.0

Magnetic Levitation Technology Deployment Program

The Federal Railroad Administration (FRA) was directed by the Transportation Equity Act for the 21st Century ("TEA-21") to initiate a competition to plan and build a magnetic levitation (maglev) project somewhere in the United States. Federal funding consists of $55 million for preconstruction planning and identification of the most promising project, and up to $950 million for final engineering and construction of the guideway of the one-selected project. The Federal funds for planning and construction must be matched at least 1/3 to 2/3 by State, local, or private contributions. To be eligible for Federal construction funding, each project must demonstrate that operating revenues will exceed operating costs, and total benefits will exceed total costs over a 40-year period, and the service must achieve a speed of at least 240 miles per hour in revenue service for some portion of the route.

Why a Priority?

Intercity travel demand and resulting congestion continue to increase. In 1998, 15 large hub airports in the U.S. were congested and 21 conservatively can anticipate congestion by 2008. Statistics of the FHWA show that in the period 1985-1995, highway traffic has grown an average of more than 3 percent per year. USDOT expects growth to continue at a rate of at least 2 percent per year. Meanwhile, the *1999 Urban Mobility Report* by the Texas Transportation Institute estimates that the costs of urban congestion in a sample of 68 urban areas was approximately $72 billion per year, with average delay per driver having increased by 181 percent from 1982 to 1997. Anecdotal evidence indicates the problems have grown since then. Growth in transportation demand over the next decades will require both new capacity and new technology to meet the nation's needs.

Maglev represents an alternative to existing means of transportation in some high-density corridors. It is the first new mode of transportation to be considered for deployment since the introduction of the airplane in 1904. Besides very high-speed capabilities, maglev features high acceleration and braking capability, an ability to climb steep grades, automated operation, variable train length, high system capacity, light vehicle weight, excellent ride quality, and safe, quiet, clean operations. Extremely powerful electro-magnets levitate, propel, guide, and stop the maglev vehicles.

Objectives

The objective of this program is to work with a selected public/private partnership to cooperatively plan, finance, construct, equip, and demonstrate in revenue service at an early date (by 2010), the potential benefits of maglev technology to the American people. If it lives up to its potential, maglev will be ready to be deployed as a logical technological successor to the Acela Express and other high-speed service currently being initiated in the Northeast Corridor and in other high-density travel corridors around the country.

Preconstruction Planning

In October 1998, FRA solicited applications for preconstruction planning grants from States or authorities designated by States. Eleven applications were received, which were evaluated in terms of the likelihood that the projects would be able to meet the eligibility standards. In May 1999, the Secretary of Transportation announced that seven projects were selected to receive planning grants in the first phase of the competition. These were:

1. **Atlanta, Georgia:** First 50 kilometers (31 miles) of a 176-kilometer (110-mile) maglev project linking Atlanta Hartsfield Airport located south of the Atlanta urban center to Atlanta and Chattanooga's Lovell Airfield along Interstate Highway Route I-75.
2. **Baltimore, Maryland to Washington, D.C.:** A 64 kilometer (40-mile) project linking Camden Yard in Baltimore (a sports complex, convention center, and center for recreation and tourism), and Baltimore-Washington International Airport to Union Station in Washington, D.C.
3. **Las Vegas, Nevada to the California State Line at Primm, Nevada:** A 56 kilometer (35-mile) project visualized by the project sponsors as the first stage of a high-speed service linking Las Vegas to Barstow and Anaheim, California, along the I-15 Interstate Highway Corridor.
4. **Los Angeles, California:** Plans for this project call for a 148 kilometer (92-mile) system would provide high-speed service between major activity centers in a dispersed high-density urban area extending from Los Angeles International Airport through Los Angeles to the downtown Union Station, then east through the San Gabriel Valley to emerging centers at Ontario International Airport and the former March Air Reserve Base in Riverside County.
5. **New Orleans, Louisiana:** This would be a 77 kilometer (48-mile) project linking New Orleans Union Passenger (Train) Terminal in the New Orleans central business district (CBD) to the New Orleans International Airport and across Lake Pontchartrain to the fast-growing northern suburbs of New Orleans.
6. **Pittsburgh, Pennsylvania:** A 76 kilometer (47-mile) project linking Pittsburgh International Airport to Pittsburgh and its eastern suburbs.
7. **Port Canaveral to Kennedy Space Center and Space Coast Regional Airport at Titusville, Florida:** A 29 kilometer (18-mile) project linking a major cruise ship port at Port Canaveral to the Kennedy Space Center and the Space Coast Regional Airport.

Evaluation and Selection of Projects

Each of the seven projects submitted a Project Description to FRA on June 30, 2000. The Project Descriptions include:

- Projected environmental effects.
- Costs of construction, equipment, and operations and maintenance.

- Estimates of ridership and revenues.
- An implementation schedule.
- Operating plans.
- A management plan defining a public/private partnership that would plan, finance, construct and operate the project.
- A comprehensive financial plan.

A multi-disciplined committee comprised of Department of Transportation staff reviewed the 7 competing Project Descriptions. The committee reported to the Secretary on the merits of each project—to assist him in selecting the most promising projects to receive continued Federal support for the next phase of pre-construction planning.

The USDOT selected the projects in Maryland and Pennsylvania to continue to the next stage of the program.

The project in Maryland has been under study since 1994. Preliminary studies indicate the project would serve between 20,000 and 40,000 trips per day, even with continued Amtrak service in the corridor. It would provide residents and visitors to Washington, D.C. with a second airport only 15 minutes from Union Station and take some of the pressure off Reagan National Airport that is currently operating at capacity with rationing of gate slots. The project is visualized as the initial stage of a high-speed maglev system that would serve the entire Northeast Corridor between Boston and Charlotte, NC. In the event the Baltimore-Washington area wins its bid for the 2012 Olympic designation, the system would provide rapid transportation between the sports venues in both cities and the airport.

The Pennsylvania project has been under study since 1990 and has two objectives. One is to demonstrate the first high-speed maglev project in the United States. The other is to establish the precision fabrication technology to implement maglev technology anywhere in the United States. The rugged physical terrain, a full four-season climate, and stops at an airport, downtown, and in the suburbs would demonstrate the full potential of maglev technology to provide service in a variety of environments. The project is intended to be the first stage of a system that would eventually provide high-speed intercity service to Cleveland on the west and Philadelphia on the east.

A Final Programmatic Environmental Impact Statement was published and distributed on April 20, 2001 that selected the "action alternative" to continue the program as the preferred alternative, and identified the Maryland and Pennsylvania projects for continued evaluation and project development. The selection was documented in a Record of Decision dated June 29, 2001. The Secretary of Transportation may select one of these projects for possible design and construction based upon more detailed information. Any decision to proceed with the construction phase would be contingent upon Congressional appropriations and completion of a site-specific Environmental Impact Statement for the selected project.

Expected Outcomes

Over the period through mid-2003, the two selected project teams will use additional funding provided by FRA and local sources to refine proposed plans, estimate ridership and revenues, prepare site-specific Draft Environmental Impact Statements for each project, and secure financial commitments. The information generated in this process will enable the USDOT to make a well-informed selection of a single project. It is anticipated that early in 2003, the USDOT would be in a position to select a single project; and later that year, upon completion of a final EIS for the selected project, to make the decision to proceed with construction. That decision would also be contingent upon whether construction funds become available in a future Federal budget.

Although not selected to participate in the next phase of the Maglev Deployment Program, the projects in California, Florida, Georgia, Louisiana, and Nevada were encouraged to continue to develop their plans and seek alternative sources of financing. To assist them, FRA has made available almost $1 million in Federal funds for each of the projects, as specified by Congress in the FY 2001 Appropriation Act.

Between now and 2003, the FRA will administer the planning grants and monitor the work of each of the project sponsors. In addition, since maglev comes under the jurisdiction of the Federal Railroad Safety Act, FRA must approve the design and operational plan for a maglev project through FRA's safety rule-making process. During this period, FRA will analyze these designs and plans from a safety assurance viewpoint. Since the Federal Republic of Germany has already conducted a similar process with regard to implementation of the same Transrapid maglev technology in Germany, USDOT has signed an agreement with its counterpart department in Germany to share safety-related and project development information.

TABLE 6.1

PLANNED TIMELINE FOR THE MAGNETIC LEVITATION TECHNOLOGY DEPLOYMENT

	FY2001	FY 2002	FY 2003	FY 2004	FY 2005
Additional Studies & Single Project Selection	●——●				
Completion of Site-specific EIS & Final Design	●———	————	——●		
Record of Decision to Design & Build		●———	——●		
Construct Demonstration Project				●———	———▶

chapter 7.0

Strategic Workforce Planning

The Government Performance and Results Act requires that strategic plans include a description of the human resources required to meet the goals and objectives. Strategic workforce planning is the tool for identifying human resource requirements, and FRA recognizes that it must undertake strategic workforce planning to make sure that the organization has the human resources it needs to accomplish its mission as described in this Five-Year Plan for RD&D. The strategic goals and the strategies that are laid out in the Plan will provide the guidance needed to permit the development of a coherent and compatible plan to retain, hire, and develop the workforce.

FRA is undertaking a seven-step strategic workforce planning process for the Office of R&D similar to that undertaken at the John A. Volpe National Transportation Systems Center, an organization that provides significant technical support to FRA. The process involves the following steps:

1. Build leadership commitment.
2. Develop a profile of current projects and workforce.
3. Link the project base to strategic goals.
4. Collect data on future resource requirements.
5. Identify workforce planning objectives and analyze the issues potentially impacting the ability to meet them; develop strategies and plans.
6. Evaluate workforce planning process and results.
7. Revise process/results based on findings.

Preliminary findings of the R&D strategic workforce planning process are summarized as follows:

> The FRA R&D Program consists of 10 program areas, each of which requires high level, specific skills and training. Many of these areas today have only one staff member working the specialty as a program manager, and 60 percent of these staff members are eligible to retire within the next five years. The lack of a succession for each area is significant and critical.
>
> FRA R&D program managers possess the technical skills necessary to oversee the many research contracts that are aimed at the overall goal of reducing the rate of rail-related crashes, injuries and fatalities in the United States. Prior to contracts being let, R&D employees must have had an understanding of the research needs in all areas of railroad safety and technology and they must have had the ability to translate those needs into comprehensive documents upon which research programs can be based.

R&D program managers possess technical skills sufficient to review, comprehend, and interpret technical reports and papers presented at technical forums such as at the TRB, AREMA, AAR, APTA, and others.

R&D program managers oversee testing at the TTC, where testing is conducted on a wide variety of railroad rolling stock and track components. This requires a keen understanding of testing methodology, application, and ramifications. Skills also required for the overseeing of this facility include understanding property management, dealing with state and local community groups, as well as the full range of engineering skills.

Skills associated with the handling of hazardous materials are required of R&D program managers. Understanding the impact of the railroad environment to the tank cars—the pulling and compressing on cars during starting and stopping, the terrain of the area, etc.—all impact the movement of hazardous materials.

In addition to researching and understanding the inanimate aspects of railroad safety, R&D program managers must understand how human factors impact safety. Research projects that cover such topics as grade crossing driver behavior, grade crossing accident causation, dispatcher workload stress and fatigue, yard and terminal safety, digital communications research, cab ergonomics, and many others are overseen by R&D staff. Industrial psychology skills are required, as are program management and evaluation skills; process analysis skills; and the like.

In addition to the technical skills required, R&D program managers must also possess communication skills, contract management skills, and leadership skills. Often an R&D staff member will be the only representative of FRA attending a national or international conference. It is not enough for these individuals to know their technical subject area. They must also know how to communicate that knowledge in a politically sensitive manner with an eye to creating mutually beneficial partnerships with diverse members of the railroad industry. Because so much of the workload of R&D staff is the management of outside contracts, they must be expert managers, as well as, evaluators of the specific technical tasks to be accomplished by the contract. And they must possess leadership skills because as the railroads themselves reduce the amount of R&D work being done, FRA is expected to fill the void and to serve as the leader.

R&D program managers believe that their workload will increase over the next five years. With the extraction of other parties away from the R&D effort, the responsibility will increasingly fall to FRA's Office of R & D. Tolerance for railroad accidents continues to decrease, causing the demand for stricter safety standards, and the research and testing necessary to create them, to increase.

Additionally, the R&D program managers cite the increasing demands of technological changes as having a major impact on the type of work that will be added in the next five years. All current employees constantly must keep abreast of these changes—changes in Intelligent Transportation Systems, changes in how the Internet can facilitate information dissemination, and changes in ways of doing business. These are things that companies in the private sector are pursuing with a competitive vengeance and that the FRA must match. Technology, information, and computers have not eased the workload of R&D. Rather, they have greatly opened the door of what needs to be researched and have increased the expectation that the new areas will be researched.

A long-term goal of the office is to have at least two research program managers in each of the ten program areas—one senior and one junior—and three additional administrative support persons to enable it to increase its output and disseminate the results to its various customers.

No staff member could identify skills that no longer will be required. Continual upgrading of the following skills must occur: systems analysis, systems engineering, transportation (railroad) planning, statistical analysis, operations research, economics, and program management.

Additional skills and skills enhancements must also occur in the areas of: telecommunications (both analog and digital); new types of radioactive materials, spent fuels, and newly created toxic and poisonous materials; smart transportation-related computer programs and research; process management and program evaluation; reliability engineering; new and upgraded computer programs, and all forms of electronic information management.

The Office of R&D currently has the most diverse workforce in FRA and one of the most diverse workforces in the Federal government. No difficulty is expected in retaining the level of diversity because of the diversity that exists now in most graduate schools of engineering.

New strategies must be developed and implemented to attract new employees with the skill mix necessary to continue the mission of the agency. Since FRA is competing with a private sector market that can pay more than is currently being paid by FRA, the challenge to devise a creative competitive pay plan is critical. Constraints on hiring could impede the hiring of greatly needed workers. More flexibility is needed also to provide incentives for highly skilled employees to remain with the Office of R&D. Repeatedly, employment research has suggested that it costs far less to retain an excellent employee through the use of certain incentives than it does to incur the cost of repeatedly rehiring and retraining new employees.

Professional Capacity Building

The NSTC's *National Transportation Science and Technology Strategy* and the *Department of Transportation Strategic Plan i*dentify the need to undertake transportation education and training to attract and maintain an educated workforce. FRA proposes initiatives to build professional capacity in response to that goal. The Federal Government has an appropriate and vital interest in assisting railroads to improve safety and improve performance, and professional capacity building is a means to those ends.

New digital communication technologies, information technologies, satellite positioning technologies, and sensor and telemetry technologies offer the potential to create Intelligent Railroad Systems, described in Chapter 2, which will radically improve the safety and efficiency of freight, intercity passenger, and commuter railroads. However, unless FRA's staff and managers, along with the management and employees of railroads, railroad suppliers, and State and local governments are educated and trained in these technologies, these technologies simply will not be implemented on railroads and their benefits will be lost. Planners must be also be educated in these Intelligent Railroad Systems technologies as well as high-speed rail and magnetic levitation technologies if these systems are to be implemented. In the short term, the focus of activities in this area will be training and re-training of FRA staff.

FRA intends to consult with the AAR, ASLRRA, APTA, Amtrak, and railroad unions to conduct an analysis of the needs for education and training in these technologies in the coming year, and in subsequent year's curriculum development and actual training could occur. This program would be based on the professional capacity building programs being undertaken by the ITS Joint Program Office and the FTA, which are now in their sixth year, and would use the staff of those programs, perhaps with augmentation, to carry out the needs analysis. It is possible that, in subsequent years, the staff of the Federal Highway Institute, which administers the ITS and FTA professional capacity building programs, could also carry out the education and training activities for FRA.

The Budget for FRA Research, Development, and Demonstration Activities

The enacted budgets for FY 2001 and 2002 and the requested budget for FY 2003 for the Research and Development and the Next Generation High-Speed Rail programs in the Five-Year RD&D Plan are presented in Table 8.1.

Appropriations for FRA's R&D and Next Generation High-Speed Rail Programs over the years are shown in Table 8.2. The variations in the appropriations reflect changing attitudes on the part of Administrations and Congresses regarding the need for railroad RD&D and the appropriate role for the Federal Government in railroad RD&D. By seeking input for all portions of the railroad industry, including its employees, customers, and suppliers, FRA hopes that this Five-Year RD&D Plan will provide a basis for future Administrations and Congress to provide funds for a targeted railroad RD&D program at FRA.

TABLE 8.1

FRA Research, Development, and Demonstration Budgets for FYs 2001, 2002 and 2003

Budget Activity	FY 2001 Enacted (in $ thousands)	FY 2002 Enacted (in $ thousands)	FY 2003 Request (in$ thousands)
RESEARCH AND DEVELOPMENT PROGRAM			
Railroad System Safety	4,640	5,150	3,225
Human Factors	2,791	3,278	3,478
Rolling Stock and Components	1,284	2,187	2,487
Track and Structures	4,640	6,325	4,225
Track/Train Interaction	3,043	3,350	3,350
Train Control	0	0	1,250
Grade Crossings	1,432	1,435	1,435
Hazardous Materials Transportation	998	1,000	1,000
Train Occupant Protection	5,338	5,350	6,450
R&D Facilities and Test Equipment	923	925	1,425
Total Research and Development Program	**25,269**	**29,000**	**28,325**
NEXT GENERATION HIGH-SPEED RAIL			
TECHNOLOGY DEMONSTRATION PROGRAM			
High-Speed Train Control Systems	10,976	11,750	10,000
Non-Electric High-Speed Locomotives	6,785	6,550	5,900
Grade Crossing Hazard Mitigation & Innovative Technologies	4,291	3,500	4,300
Track/Structures Technology	1,297	1,100	1,300
Corridor Planning Activities	1,696	5,900	1,700
Maglev	0	3,600	0
Total Next Generation High-Speed Technology Demonstration Program	**25,045**	**32,300**	**23,200**

TABLE 8.2

FRA Research, Development, and Demonstration Budget History

	Current Year Dollars (in $ thousands)	Constant 2000 Dollars (in $ thousands)	Staffing: Full Time Equivalent
Research and Development Program			
1975	47,000	125,678	85
1976	79,800	201,894	103
1977	52,900	125,796	101
1978	53,600	118,938	101
1979	51,980	106,507	107
1980	54,750	102,766	110
1981	50,000	85,800	97
1982	30,000	48,480	70
1983	17,000	26,418	25
1984	16,225	24,305	16
1985	15,525	22,557	15
1986	10,144	14,414	15
1987	9,581	13,221	15
1988	9,286	12,387	15
1989	9,286	11,932	15
1990	10,198	12,614	15
1991	17,585	20,996	16
1992	22,331	26,038	20
1993	25,205	28,683	21
1994	20,613	22,983	21
1995	20,199	22,037	20
1996	24,081	25,766	20
1997	20,092	21,096	20
1998	20,755	21,522	19
1999	22,364	22,882	19
2000	22,464	22,464	19
2001	25,269	24,738	19
2002	29,000	27,782	21
Next Generation High-Speed Rail Technology Demonstration Program			
1995	19,868	21,675	4
1996	19,127	20,465	4
1997	24,755	25,992	4
1998	20,395	21,252	5
1999	20,494	20,965	5
2000	27,097	27,097	6
2001	25,045	24,519	6
2002	32,300	30,943	6
Magnetic Levitation Technology Deployment Program			
1999	13,244	13,584	1
2000	17,420	17,420	1
2001	19,645	19,232	1
2002	3,600 (Included in Next Generation Program)	3,448	1

chapter 9.0

Conclusion

This *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations* started with the idea that innovations in railroad research and technology could play an important role in producing a safer, more efficient transportation system. By doing so, this plan addresses the goals of the FRA and USDOT Strategic Plans called for by the Government Performance and Results Act. In addition, consultation on this Five-Year Plan for RD&D identified the need to address issues in these and other areas. Other major areas were: worker ergonomics, crew resource management, protection of train occupants, safety evaluation of software-based systems, improved detection of track and equipment defects, and building capacity for the next generation of transportation professionals.

The ten R&D program areas: railroad system issues, human factors, rolling stock and components, track and structures, track-train interaction, train control, grade crossing, hazardous materials, train occupant protection, and R&D facilities and equipment; the four Next Generation High-Speed Rail Technology Demonstration program areas, train control, non-electric high-speed locomotives, grade crossings, and track and structures; and the Magnetic Levitation Deployment program, were identified from strategic thinking, industry input, and ongoing research, development, and demonstration programs. Goals, and activities for achieving the goals, were established around each of these areas. Activities were mapped in priority order over the five-year horizon.

Progression toward the five-year goals occurs in two forms: short-term and long-term efforts. In the short-term, year’s one and two, FRA will strategically adjust the RD&D program as ongoing projects are completed, mainstreamed, or phased out, new, more strategically derived projects are set in motion.

New projects may include the development of crashworthy commuter rail vehicles, development of a 5- to 10-car train to demonstrate improved monitoring capabilities, safety assessments of new intermodal equipment, studies of the effects of boredom and inactivity on train crews, the development of tactical and strategic traffic planners, research into the application of security technologies to railroads, and the development of tools for automated measurement of track settlement and transitions.

Research and technology development is an ongoing, iterative process that must be both forward looking and flexible enough to address new needs. This Five-Year RD&D Plan has been developed with industry consultation to meet identified needs of the railroad industry. It is flexible enough to address new needs and to take advantage of new opportunities. FRA will continue to: (a) work with all parts of the railroad industry, (b) use its R&D project development and selection process, and (c) have a peer review program under the auspices of the Transportation Research Board. Changes will be made to the Plan when necessary to meet the needs of the Federal Government, the railroad industry, its employees, its customers, and its suppliers.

No research and technology development can be conducted in isolation, and FRA is no exception. Railroad research and development is an extension of the larger research activities in this country. Basic research in subjects such as information systems, communications, advanced materials, and computer applications are all indirectly supporting the progress of railroad research. FRA fully intends to take advantage of the results of the basic system research in which the United States leads the world.

appendix A:

Relationship to Other Strategic Plans

FRA's *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations* ("Five-Year Plan for RD&D") reinforces ongoing activities addressing the need for a strategic approach to railroad research and technology. The Government Performance and Results Act (GPRA) requires each federal agency to develop strategic goals, plans, and performance measures with participation and feedback from external customers. Strategic plans recently completed by the National Science and Technology Council (NSTC) of the Executive Office of the President of the United States, the U.S. Department of Transportation (USDOT), and FRA, established the foundation for the development of this Five-Year Plan for RD&D. These strategic plans are the product of extensive industry and government coordination and consultation. Their relationships are shown in Figure A.1.

The NSTC's *National Transportation Science and Technology Strategy,* April 1999, presented a four-tiered approach to preparing for twenty-first century transportation challenges and opportunities:

1. Strategic Planning and Assessment.
2. Private-Public Technology Partnerships.
3. Enabling Research.
4. Transportation Education and Training.

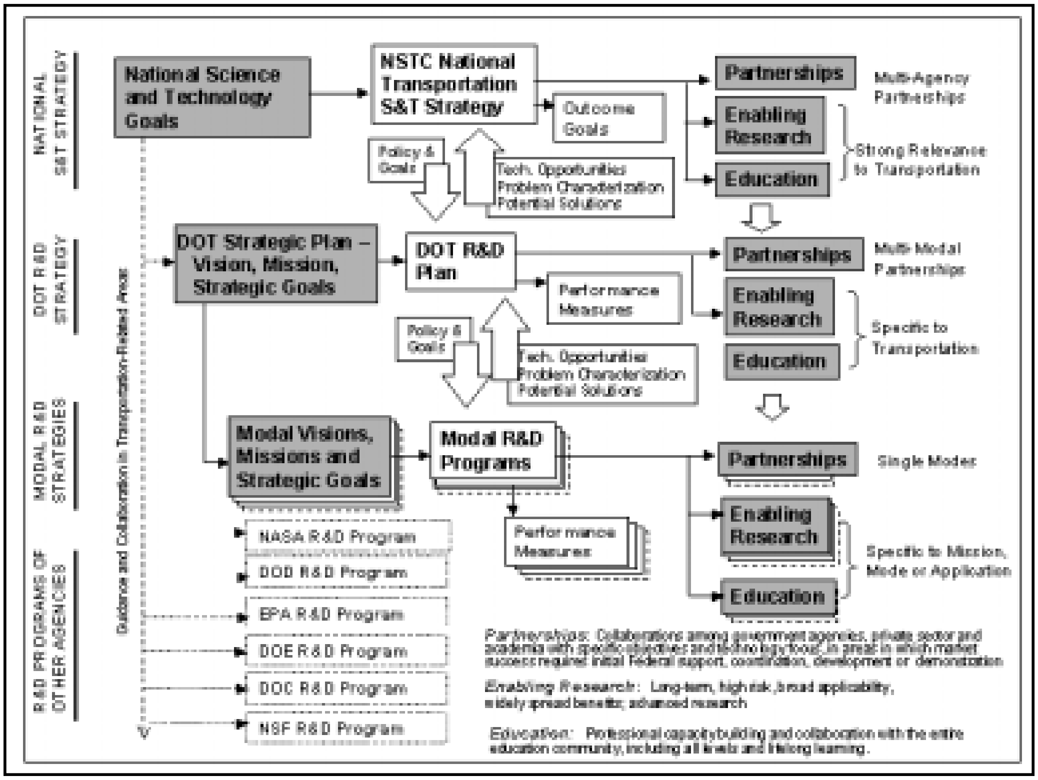
Subsequent NSTC plans were developed in accordance with this four-tiered approach. The National Strategy's ultimate goal is to bring together all partners in the transportation enterprise —Federal, State, local, and tribal agencies; academic institutions; and the private sector—to ensure a safe, efficient, sustainable, and secure transportation system for America. Through science and technology, the National Strategy states, "America can achieve a transportation system that is fast, safe, efficient, accessible, and convenient."

The NSTC's *National Transportation Technology Plan,* published in March 2000, presented implementation strategies for partnership initiatives. Thirteen partnerships were identified, and five of them involve railroad technology. The five partnerships and the related FRA programs are:

- Next Generation Transportation Vehicles - High-Speed Turbine-Powered Locomotive.
- National Intelligent Transportation Infrastructure - Nationwide Differential GPS and Positive Train Control.

Figure A.1

DOT R&D Strategic Planning Process



- Transportation Infrastructure Assurance - Railroad System Issues, and Track and Structures R&D.
- Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure - Track and Structures R&D.
- Enhanced Transportation Weather Services - Railroad System Issues.

These and other strategic partnership initiatives being carried out by FRA are described in subsequent sections of this Five-Year Plan for RD&D.

The NSTC's *National Transportation Strategic Research Plan*, published in May 2000, defines three "breakthrough" research areas and six long-term research areas as a structure for analyzing Federal transportation-related enabling research. The three breakthrough areas that could significantly alter and expand the technological options available to the transportation enterprise, along with representative applications from the FRA R&D program are:

- Nanotechnology - sensors for track and rolling stock.
- Bio-fuels - alternative locomotive fuels.
- Complex Systems and High-Confidence Software - Positive Train Control.

The six long-term applied research areas, along with representative applications from the FRA RD&D program, are:

- Human Performance and Behavior - Railroad Dispatcher Stress and Fatigue Studies.
- Advanced Materials and Structures - Composite Materials for Railroad Bridges and Trestles.
- Computer, Information, and Communication Systems - Positive Train Control.

- Energy, Propulsion, and Environmental Engineering - High-Speed Non-Electric Locomotives.
- Sensing and Measurement - Track Strength Measurement Systems.
- Analysis, Modeling, Design, and Construction Tools - Advanced Rail Vehicle Crash Simulation Tools.

These and other enabling research activities being carried out at FRA are referred to in greater detail in subsequent sections of this Five-Year Plan for RD&D.

The NSTC's *Transportation Infrastructure Assurance Research and Development Plan,* developed in June 2000, addresses critical physical and information infrastructure elements as follows:

- Physical security of transportation modes and intermodal connections.
- Security of vital communications, radio navigation, and information systems and networks.
- Susceptibility of transportation operators and users to chemical, biological, and radiological threats.
- Development and dissemination of information about system threats, vulnerabilities, and best practices to transportation system developers, operators, and users.

This Five-Year RD&D Plan for the first time describes activities that FRA will be undertaking to help ensure railroad system security.

The *U.S. Department of Transportation Strategic Plan 2000-2005*, issued by the Secretary of Transportation in July 2000, provided additional guidance for FRA's strategic planning activities. It includes the following Vision Statement, Mission Statement, and Strategic Goals, all of which are reflected in this Five-Year Plan for RD&D:

Vision Statement:

A visionary and vigilant Department of Transportation leading the way to transportation excellence in the twenty-first century.

Mission Statement:

Serve the United States by ensuring a safe transportation system that furthers our vital national interests and enhances the quality of life of the American people.

Strategic Goals:

1. Safety: Promote the public health and safety by working toward the elimination of transportation-related deaths and injuries.
2. Mobility: Shape an accessible, affordable, reliable transportation system for all people, goods, and regions.
3. Economic Growth: Support a transportation system that sustains America's economic growth.
4. Human and Natural Environment: Protect and enhance communities and the natural environment affected by transportation.
5. National Security: Ensure the security of the transportation system for the movement of people and goods, and support the National Security Strategy.
6. Organizational Excellence: Advance USDOT's ability to manage for results and innovation.

The Organizational Excellence Goal employs six strategies for accomplishing outcomes:

1. Exert leadership throughout the transportation enterprise by articulating a vision and setting future direction.

2. Provide top quality customer service.
3. Achieve results by empowering our employees to realize their full potential.
4 . Set the standard for e-government.
5. Improve our services and processes through innovation, new technology, and proven management techniques.
6. Accelerate the use of new transportation technologies.

The strategies for innovation, research, and development in the *U.S. Department of Transportation Strategic Plan 2000-2005* are aimed at accelerating the use of new technologies and fostering long-term and high-payoff enabling research. They include:

A. Provide leadership within the Federal Government for transportation R&D, and within USDOT, align R&D, sponsored by the operating administrations, with USDOT's strategic goals.

B. Ensure a balanced R&D portfolio that addresses the critical, long-term transportation needs of USDOT and the nation through an annual National Research Council peer review of DOT's R&D proposals.

C. Leverage long-term research within USDOT and across the Federal Government by bringing together communities of common interest, identifying areas for collaboration, and implementing a long-term transportation research and education program for the Nation.

D. Eliminate regulatory and legal barriers that slow the innovation process and hinder the deployment of new technology.

E. Develop and extend public-private partnerships to enable greater information diffusion, quicker product development, and faster rates of learning.

The *U.S. Department of Transportation Research and Development Plan, 2nd Edition,* published in May 2000, describes the close relationship between USDOT strategic goals and those outlined by the NSTC as reflected in transportation R&D. It also describes the R&D Management Strategy for the Department:

- Strategic Planning - The annual USDOT Transportation R&D Plan will provide the strategic framework for aligning USDOT R&D activities with the USDOT Strategic Plan, and annual Performance Plan and Report, the NSTC Transportation Science and Technology Strategy and implementation plans, and requirements outlined in TEA-21 and FAA authorizations.
- World-Class Transportation R&D Capability - To ensure that in-house R&D organizations are technical centers of excellence, USDOT will assess their performance relative to the FY 2000 baseline, using Malcolm Baldrige, or President's Quality Award Criteria, ISO 9000, or the Software Engineering Institute's Capability Maturity Model certification.
- R&D Tracking - To ensure decision makers have complete, accurate, and timely information on USDOT R&D activities, USDOT is developing a comprehensive R&D tracking system.
- Peer Review - USDOT aims to ensure that its R&D portfolio is balanced and addresses the critical long-term needs of the USDOT and the Nation. To this end, the Transportation Research Board's Committee for the Review of the National Transportation Science and Technology Strategy now conducts an annual assessment of USDOT's R&D plans and programs, and how they contribute to achievement of Departmental goals articulated in the *USDOT Strategic Plan* and the *USDOT Annual Performance Plan and Report.*

The *FRA Strategic Plan*, published in June 2001, is based on the *Department of Transportation Strategic Plan*, and on information gathered on national and international trends, likely changes in railroading, and the needs of its customers and stakeholders. Dramatic changes occurring in virtually every area of railroading demand that the FRA respond flexibly and quickly to maintain the high safety record of railroading in the United States. Additionally, the FRA has a commitment to ensure that new technologies to improve system safety and efficiency are brought on line expeditiously.

The *FRA Strategic Plan*, like the *Department of Transportation Strategic Plan*, has six strategic goals:

1. Safety - Promote safety by working toward the elimination of rail-related fatalities, injuries, and incidents.
2. Mobility - Promote an accessible, reliable rail transportation system that meets the needs of freight customers and rail passengers.
3. Economic Growth - Support a rail transportation system that sustains America's economic growth.
4. Human and Natural Environment - Protect and enhance communities and the natural environment affected by rail transportation.
5. Security - Support the secure movement of people and goods, on the Nation's rail transportation network.
6. Organizational Excellence - Promote FRA's ability to achieve program results.

Under the Safety goal, FRA commits to the following RD&D-related activities:

- Conduct research and development to support rail safety rulemaking and safety assurance.
- Develop and demonstrate a model Positive Train Control (PTC) system and work with the industry to develop standards for interoperable PTC that can be implemented economically.

Under the Mobility goal, FRA commits to the following RD&D-related activities:

- Conduct research, development and demonstration of technologies that enhance the feasibility of high-speed rail applications in the U.S.
- Implement the Maglev Deployment Program, with a goal of demonstrating a high-speed maglev system in revenue service in the U.S.
- Complete implementation of the Nationwide Differential Global Positioning System (NDGPS).

Under the Economic Growth goal, FRA commits to the following RD&D-related activities:

- Conduct policy research and analysis leading to the improvement of the economic efficiency of the rail system.
- Conduct research and development that could lead to improvement in rail industry efficiency, particularly when done in conjunction with work which has safety benefits.

Under the Human and Natural Environment goal, FRA commits to the following RD&D-related activities:

- Conduct research on the use of alternative fuels and other energy conservation and environmental quality improvement actions related to railroads.

The Intelligent Transportation Systems Joint Program Office in USDOT published the *National Intelligent Transportation Systems Five-Year Program Plan.* It lays out the goals, activities, and milestones for the National ITS Program from fiscal year 1999 through 2003. Included in the Plan is an update on the ITS user services, including substantial information on user service #30, the Highway-Rail Intersection User Service. Also, included as emerging program activities that have FRA involvement, are intermodal freight and rail transit.

The Federal Transit Administration published its *Transit Research & Technology Five-Year Plan* in October 1999. The Plan established six program areas:

1. Safety and Security

2. Equipment and Infrastructure
3. Fleet Operations
4. Specialized Customer Services
5. Policy and Planning
6. Professional Capacity Building

In the preparation of the FRA Five-Year Plan for RD&D, the staff of FRA's Office of Railroad Development coordinated closely with the staff of the FTA to ensure that matters dealing with commuter rail facilities, rolling stock, and operations were dealt with in a consistent manner in both the FTA and FRA plans.

The American Public Transportation Association also published its *Strategic Plan 2000-2004* in October 1999. It established six strategic goals:

1. Ridership and Business Opportunities.
2. Advocacy.
3. People and Organizations.
4. Image
5. Safety and Security
6. Membership Development

FRA staff works closely with APTA staff on safety and security matters, and in particular on crashworthiness, to create a safer and more secure environment for commuter rail riders, workers, and the public at large.

The Association of American Railroads, through its wholly-owned research subsidiary, Transportation Technology Center, Inc., has established, and is responsible for carrying out a *Strategic Research Program* to improve the safety and efficiency of the North American railroad industry. The Program consists of twelve Strategic Research Initiatives:

1. Wheel/Rail Asset Life Extension
2. dvanced Train Equipment. *
3. Vehicle Track Performance. *
4. Facility for Accelerated Service Testing (FAST)/ Heavy Axle Load (HAL) Operations. *
5. HAL Revenue Service Evaluation.
6. Intelligent Train Systems - Assisted Train Control. *
7. Train Condition Monitoring. *
8. Track Integrity Monitoring. *
9. Special Track Work.
10. Bridges
11. Track Components*
12. Signal System Research. *

FRA has entered into a formal partnering agreement with the AAR. Asterisks indicate those Strategic Research Initiatives in which there is active involvement by and joint funding with FRA. More information on the specific projects is provided in Chapter 4 of this Five-Year Plan for RD&D.

The staff of FRA's Office of Railroad Development has participated actively in the preparation of most of the aforementioned plans. This ensures that there is consistency between this Five-Year Plan for RD&D and other governmental, departmental, agency, and private sector strategic plans.

appendix B:

University Research Grants, Small Business Innovative Research, and IDEA Programs

FRA UNIVERSITY RESEARCH GRANTS PROGRAM

Purpose: This Program enhances FRA's safety R&D program by developing cooperative research relationships with selected academic institutions. In doing so, FRA is establishing Strategic Partnership Initiatives, and supporting Transportation Education and Training. Each year, a small number of grants are awarded with a typical value in the range of $100,000 to $200,000 and a combined value of about one million dollars. Applicants are encouraged to consider sharing the cost of their proposed projects or identify in-kind contributions. Awards are made to universities that have expertise that complements FRA's R&D program.

Approach: Announcements are normally published in the Federal Register once every three years soliciting proposals from accredited academic institutions in identified areas of research. Applicants must have demonstrable expertise in rail transportation research, and have a minimum of five years of rail-related research experience. Each proposed project in each area of interest is evaluated on the following criteria: (1) overall scientific and/or technical merit; (2) the degree to which it may improve railroad safety; (3) the likelihood for near-term adoption of the research results; (4) the extent to which the proposal fits into the FRA's overall research program; and (5) the reasonableness and realism of the proposed cost, and the availability of funds to include consideration of proposed cost-sharing (cash or in-kind contributions). Qualified applications are ranked in order of qualifications, probability for success, and the degree to which the proposed project fits into the FRA's overall research program.

SMALL BUSINESS INNOVATIVE RESEARCH (SBIR) PROGRAM

Purpose: This program stimulates technological innovation, uses small business to meet federal research and development needs, increases private sector commercialization of innovations derived from Federal research, and encourages participation by small, disadvantaged companies in developing technological innovations. The Small Business Research and Development Act of 1992 authorized the SBIR program. This program is funded through project funds that reside in other R&D programs, and thus benefits the entire program spectrum. The budgetary and technical resources can be applied to these programs in a timely and cost-effective manner. By enabling small, high technology companies to start up and prosper, the SBIR contributes in a larger sense to the domestic economy and technology infrastructure.

Approach: The program is administered by the Volpe Center for all USDOT Operating Administrations. Research topics are solicited from the various agencies throughout the Department, and the topics appear in an annual solicitation for proposals issued by the Volpe Center. Individuals who submit the topics evaluate the proposals, and winners are chosen based on evaluations and agency needs. Firms selected to receive an award embark on the following three-phase process: Phase I - conduct feasibility-related experimental or theoretical research for R&D efforts up to $100,000; Phase II - perform principal research effort with a performance period of approximately 2 years and funding up to $750,000; and Phase III - perform commercialization of the research conducted under Phases I and II, with no funding limit. Phase III is to be conducted with either non-Federal funds or non-SBIR government funded contracts.

TRANSPORTATION RESEARCH BOARD IDEA PROGRAM

Purpose: The TRB IDEA (Ideas Deserving Exploratory Analysis) program explores the feasibility of unproven technical concepts, novel applications of proven concepts, or advances that have not yet been tried or tested for application in transportation practice. The TRB is a unit of the National Research Council, which is the principal operating agency of both the National Academies of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The IDEA program focuses on high-payoff concepts, or advances that have not yet been tried or tested for application in transportation practice, products, systems, tools, or techniques that accelerate the development and deployment of advanced technologies, methods, or processes for surface and intermodal transportation systems.

IDEA projects are product- or results-driven investigations. An IDEA award is a one-step process designed to carry out an assessment of a concept or novel application of a product or result for transportation practice. The IDEA program is not intended to provide continuing support for basic or long-term research or to evaluate commercially available products used in transportation practice. The program solicits proposals on innovative concepts applying advanced communications, information, sensor, and automated control technologies or other concepts that can advance the deployment of high-speed intercity passenger rail service in the United States.

The High-Speed Rail IDEA program is administered by the TRB and is funded jointly by the FHWA, NHTSA, FTA, and FRA. The selection of IDEA projects is based on the uniqueness of results for HSR and HSR deployment in support of the USDOT national program on ITS.

The Transportation Safety Technology IDEA Program, initiated in FY 2001, is administered by TRB and is funded jointly by NHTSA, FMCSA, and FRA. It explores the feasibility of new technical concepts and methods that have potential to significantly enhance transportation safety, but that have a high enough degree of uncertainty that they aren't likely to find financial support from other sources. TST-IDEA will solicit proposals for projects to develop or test innovative transportation applications, it will maintain a committee of experts to select the most promising proposals, and it will administer the selected projects through contracts with the proposing individuals or organizations.

Approach: Research topic areas are solicited from the various Operating Administrations in USDOT. The topic areas then appear in an annual solicitation for proposals issued by the TRB, which convenes panels of experts to evaluate the proposals, and winners are chosen based on technical evaluations, funds availability, and probability of success of the proposed work. Cost sharing by proposers is strongly encouraged but is not mandatory. Firms selected to receive an award embark on the following process: Phase I - conduct feasibility-related experimental or theoretical research for R&D efforts up to $100,000 and Phase II - perform field demonstration (a performance period of approximately 2 years and funding up to $250,000).

appendix C:

Letter Report of the Transportation Research Board's Committee to Review the FRA R&D Program