IDEA

Innovations Deserving
Exploratory Analysis Programs

HIGH-SPEED RAIL

New IDEAS for High-Speed Rail

Annual Progress Report
January 2000

TRANSPORTATION RESEARCH BOARD • NATIONAL RESEARCH COUNCIL

TRANSPORTATION RESEARCH BOARD

NEW IDEAS FOR HIGH-SPEED RAIL SYSTEMS

An Annual Progress Report of the High-Speed Rail IDEA Program

JULY 1998 – JUNE 1999

Transportation Research Board

National Research Council

HIGH-SPEED RAIL-IDEA PROGRAM COMMITTEE

FTA Staff

Venkat Pindiprolu
Program Officer

IDEA Staff

Neil Hawks
Director Special Programs

Chuck Taylor
HSR-IDEA Program Officer

Keith Gates
ITS-IDEA Program Officer

Harvey Berlin
Transit-IDEA Program Officer

Inam Jawed
NCHRP Highway-IDEA

Debbie Irvin
IDEA Administrative Assistant

TABLE OF CONTENTS

SECTION 1: Completed Projects

SECTION 2 Active Projects

INTRODUCTION

IDEA (Innovations Deserving Exploratory Analysis) Programs explore promising but unproven concepts with potential to advance surface transportation systems. The High-Speed Rail (HSR)-IDEA Program is funded by the Federal Railroad Administration (FRA). HSR-IDEA projects are selected for their potential role in upgrading the existing U.S. rail system to accommodate operations up to 125 mph and beyond in support of FRA's next-generation HSR technology development program. The HSR-IDEA Program is one of the four integrated IDEA Programs managed by TRB. The other three IDEA programs are:

- NCHRP-IDEA, which focuses on concepts for advancing the design, construction, safety, and maintenance of highways;
- Transit-IDEA, which supports innovative approaches for improving transit operations and safety; and
- ITS-IDEA, which focuses on advanced electronic surveillance, communication, and information processing technologies for highway systems, safety, and intermodal systems.

Since its creation in 1997, HSR-IDEA has received $2 million in support from FRA. Prior to 1997, an additional $0.5 million was provided by the ITS-IDEA Program to support high-speed rail projects. The two programs remain closely associated since they are administered jointly by IDEA and have members who sit on both Program Committees. Together the programs have funded 91 projects, 18 of which are HSR related and reported in this document.

This report is organized by project number. Brief reports on the results of projects completed prior to 1999 appear first. Projects that were active in 1999 are more fully described and illustrated in the second section.

Since 1997, approximately 10% of HSR-IDEA awards have been to small companies (fewer than 10 employees), 70% to larger research and consulting companies, and 20% to universities. HSR-IDEA has made awards to about 20 percent of the proposals it has received.

SECTION 1

High-Speed Rail IDEA Projects Completed Prior to 1999 Project Year

HSR-1/ITS-29: Scanning Radar Antenna for Collision Avoidance

WaveBand Corporation - Torrance, California

IDEA Concept and Product

This IDEA product is a compact, low-cost, scanning millimeter wave (MMW) antenna for application to obstacle detection and collision warning for both railroads and automobiles. The Spinning Grating antenna system is unique in that it uses the phenomenon of diffraction to define and steer a beam of MMW energy in a simple and cost-effective manner. This technology was first devised for imaging radar systems for aircraft landing guidance.

This IDEA project investigated using an MMW radar with the Spinning Grating antenna to provide surveillance of highway-railroad grade crossings. The all-weather capability of scanned microwave radar can reliably detect the presence of obstacles in the path of a train to initiate preventive action.

Millimeter wave sensors are the leading candidates for providing the raw data needed by intelligent cruise control and collision warning systems for ITS automotive applications. A scanning sensor is needed to provide more complete spatial information about the roadway ahead. Unlike electronically steered antennas and more traditional gimbal-mounted antennas, the IDEA antenna will be inexpensive enough to install in passenger vehicles.

The IDEA antenna was chosen by NHTSA as a candidate for comparative testing to define requirements for collision warning and intelligent cruise control.

The California Manufacturing Technology Center, commissioned to develop a low-cost manufacturing approach, found that the antenna can be manufactured primarily of molded plastic with a few metal parts. The antenna has few pieces and can be easily assembled by a multiaxis industrial robot with minimal hand labor. The antenna will probably have just a single moving part.

The investigator has ongoing IDEA project support for application testing of scanning antenna technology to railroad crossings safety (HSR-13).

IDEA contract: $93, 974

Cost sharing: $12,020

Project total: $105,994

Start: October 1995

Complete: February 1997

HSR-2/6: Wide-Angle Video System for Grade Crossings

Intelligent Highway Systems, Inc. - White Plains New York

IDEA Concept and Product

This IDEA project explored the potential of a wide-angle, single-camera machine video system for surveillance of grade crossings. Potential uses of such a system would include detection of vehicles on crossings for sequencing of four-quadrant gates, detection of stalled or disabled vehicles, and monitoring the performance and condition of grade crossing warning system components. Other uses could be preemption of highway traffic signals to prevent backups onto railway tracks, and detection and identification of vehicles that trespass railroad tracks after warning systems have been activated.

A single 160°, wide field-of-view, all-weather optical surveillance system has been developed that could replace multiple sensors that are presently required to monitor, evaluate, or control the traffic flow within an entire crossing area. Such an area may include each inbound and outbound or exiting lane on both sides of the grade crossing.

The system is designed to provide real-time detection and tracking of the position of crossing gate arms on each side of the railway tracks, even when a train is present in the intersection. Supplemented with machine vision logic, the system provides potential for the detection of

- objects that are stopped or stuck on the tracks,
- vehicles that are waiting in a queue that extends to within a critical distance of the tracks,
- malfunctioning crossing signals or gates, and
- objects that cross the tracks in violation of crossing signals.

Project Progress

The exploration of this concept for surveillance of an entire, non-orthogonal, omni-directional traffic intersection, rotary, or freeway using a single camera system was the objective of an IDEA project completed in July 1996 (HSR-2). Application for highway-rail grade crossing surveillance was the objective of this follow-on IDEA project (HSR-6). Project tasks included refinement of the system software for application to grade crossings, and field testing on active crossings. The system was designed to monitor the crossing and adjacent roadways and issue predefined alert signals, e.g., when vehicles were detected in the crossing after gate activation, when any crossing warning system malfunction was detected, or if vehicles entered the crossing after the gates were activated.

HSR-6 was completed in December 1997. The contractor, Intelligent Highway Systems, has established a teaming arrangement with Nestor, Inc., another IDEA project contractor (see HSR-19), to examine the use of Nestor's neural network technology for interpretation of the video images.

Technical advisor:
Panos G. Michalopoulos,
University of Minnesota

IDEA contract: $44,250

Cost sharing: $36,075

Project total: $80,325

Start: April 1997

Complete: December 1997

HSR-3: Laser Optics Communications System

State University of New York at Stony Brook

IDEA Concept and Product

There is an increasing need for the rapid exchange of large data files between high-speed trains and wayside facilities. One example is the data exchange requirements of communications-based train control systems. These systems, which rely on on-board and central computers, navigation systems, and communications links between trains and central control facilities, require downloading and uploading of large data files such as track and route characteristics, and train-consist data. There are situations when conventional radio communications links may not always be the most effective means for such data exchanges, due to such factors as data volume, interference, and communications coverage problems.

Another example is the need to exchange health monitoring and diagnostic data for various train components. Increasingly, such data are collected and stored in computers on board locomotives. High-volume train-to-wayside communications links are required to down load such data for analysis to provide real-time diagnosis and support the scheduling and management of maintenance and repair activities.

The objective of this IDEA project was to develop a communications system using infrared laser beams and servo-controlled antenna systems to provide high-speed, high-volume data exchange between moving trains and wayside terminals.

The concept uses servo-directed laser beams to provide a communications link between a moving train and a railroad wayside terminal. This technology has the potential to transmit 10^6 bytes of information in 0.2 seconds. The servo system would enable the train-mounted and wayside antennas to track each other during the brief period in which the high volume data exchange occurs. Data communications begin when the train is approximately 30 meters from the wayside terminal, and end at a distance of approximately 10 meters. Tracking of the train and wayside terminals is controlled by servo motors that align photo-optic reflectors based on the strength of the laser signals received.

The contractor, State University of New York, worked with Telephonic Corporation, a commercial communications equipment manufacturer, to determine the most effective strategy for the development and marketing of a production version of this system.

Project Progress

HSR-3 was completed in December 1998. The definition of the requirements and specifications for a laser open-air communications system for high-speed rail application were completed. Prototypes of the train and wayside terminals, including photo-optic assemblies and servomotors, were fabricated and successfully demonstrated in a laboratory environment.

Technical advisor:
Howard Moody,
Association of American Railroads

IDEA contract: $91, 024

Cost sharing $100,000

Project total: $191,024

Start: December 1995

Complete: December 1998

HSR-4/ITS-37: Using Rail Vibration Analysis to Detect Approaching Trains

Raven Inc., Alexandria, Virginia

IDEA Concept and Product

The concept is to sense induced rail-vibration signals to detect the approach of trains for warning maintenance crews. IDEA project results indicated that vibration signatures can be used to determine train position and speed and to estimate train makeup and direction.

CSX Transportation, Inc., and the Washington Metropolitan Area Transit Authority participated in the data collection and field experimentation. A vibration sensor/analyzer showed the potential to detect a train at a distance or to determine that the train is right at the sensor. This attribute led to the design of two different devices that can be used to alert a flagman that a train is approaching. These same devices can be adapted as an inexpensive means of operating a warning system at a grade crossing.

Project Progress

This project was completed February 1997. A follow-on project (HSR-17) is underway to fabricate and test an automatic warning system for track maintenance workers.

Technical advisor:
Charles Taylor,
Association of American Railroads

IDEA Contract: $73,750

Cost sharing: $16,800

Project total: $90,550

Start: January 1996

Complete: February 1997

HSR-5/ITS-39: Proximity Warning System for Locomotives

Robert Kull, Principal Investigator,
Rockville, Maryland

IDEA Concept and Product

There is growing interest and activity among railroads, suppliers, and government agencies in the development of so-called communications based train control systems. These systems rely on sophisticated computers on board locomotives and at central train control centers, combined with train location and navigation systems, and digital data communications links for the control of train operations. They have the potential to dramatically increase the utilization of railroad track and equipment and improve safety and service reliability. These systems would replace the conventional track-circuit based signal systems and thereby allow safe operations with much shorter headways between trains to improve system throughput and increase track capacity. They would also enable the monitoring of train crews for compliance with computer-generated train movement authorities using the on-board computers, and enforce compliance if these authorities are violated through automatic brake applications.

Most of the systems developed and tested to date have required a significant infrastructure investment, with both trackside and dispatch office hardware and systems. Their highly centralized approach requires implementation on a wide scale and requires a substantial data radio communications system and trackside equipment infrastructure investment. None of these systems has been implemented beyond pilot projects to date, largely due to the large front-end costs, and the related difficulty for railroads to cost justify the investment.

The objective of this IDEA project was to develop and test a low-cost train navigation and communication system to enable location information to be exchanged between trains on a local area basis. Each locomotive could then compute the distance and relative direction of other trains in its proximity for warning the engineer of potential conflicts.

The concept of the proximity warning system is based on the integration of rail navigation and communications subsystems. A rail navigation system on locomotives uses on-board computers, GPS receivers, a gyro, and axle generator interface to determine train location and track ID using an on-board track database. Shared use of the locomotive to end-of-train data communications system provides local area data exchange with other locomotives. Trains periodically broadcast their current track ID, location, direction, speed, and routing plans, which are received by other trains in the area. A color graphics engineer display provides an illustration of the engineer's own train, as well as other trains in the area, against the track profile. The system is able to advise of potential movement conflicts based on comparison of data among trains in the area.

Project Progress

Three Burlington Northern Santa Fe (BNSF) locomotives were equipped with prototype systems and tests were conducted in August and September 1997. The IDEA project was completed in October 1997. Radio frequency communications coverage was shown to be sufficient, without need for repeater units. Initial data communications was typically achieved within a distance of about 5 to 6 miles, with consistent coverage within 3 miles.

Subsequent to the completion of this project, eight BNSF locomotives were equipped with the system for an expanded pilot project in southern California. These tests were successful and helped bring the system to a commercial product level.

Technical Advisor:
Mr. Lynn Garrison, BNSF

IDEA contract: $99,000

Cost sharing: $120,000

Project total: $219,000

Start: March 1996

Complete: October 1997

SECTION 2

High-Speed Rail IDEA Projects Active During the 1999 Project Year

HSR-7:
Pulsed LED Railroad Crossing Signals

Relume Corporation - Troy, Michigan

IDEA Concept and Product

Conventional warning systems at highway-railroad grade crossings are expensive. A system of flashing lights and gates now typically costs between $125,000 and $150,000. Moreover, analyses of grade crossing accidents reveal that highway vehicle operators don't always respond appropriately to these conventional systems, often because they cannot see that the crossing warning system has been activated by an approaching train, due to obstructions, crossing geometry, or weather conditions. As a result, railroads and local, state, and federal railroad and highway agencies are interested in innovative, low-cost alternatives that have the potential to provide more effective warnings to drivers when trains are approaching crossings.

The conventional incandescent light source used in the flashing lights of crossing warning systems is beginning to be replaced by arrays of light-emitting diodes (LEDs). The advantages include longer life and lower power consumption. Because LED signals can be rapidly pulsed, opportunities exist for modulating them to send messages to highway vehicles.

The objective of this project is an innovative, low-cost system for sending warning messages from LED arrays used at grade crossings to a small receiver that can be placed inside highway vehicles to alert drivers that the crossing system is active.

This project will develop and test a low-cost in-vehicle proximity alert system specifically designed for use by high-occupancy and priority highway vehicles such as police vehicles, emergency vehicles, HAZMAT vehicles, school buses, and transit vehicles approaching grade crossings. The system employs LED arrays to replace the conventional incandescent lights used in crossing warning lights. These LED signals are pulsed at a rate that is imperceptible to the human eye (20 kHz to 50 kHz). This pulsed signal transmits a specific code to a receiver

FIGURE 1

Flashing LED grade crossing lights.

inside the highway vehicle. When this signal is received, the in-vehicle unit emits an audible alert to the driver. A variant of the proposed system is presently being applied to pedestrian crossing signals that are being manufactured by the contractor. In this application, a small portable receiver carried by visually impaired persons advises the user of the state of the "walk" or "don't walk" light by providing an audible voice message.

Project Progress

This IDEA project is being conducted in two stages. In the first stage, modifications to the existing design for pedestrian crossing applications in highway vehicles at grade crossings were completed. These modifications include improving the range of the system to a minimum of 100 meters with angular coverage that meets or exceeds standards for vehicles approaching crossings. A project evaluation panel comprising representatives of state DOTs, FRA, and railroads was convened to review the system functional requirements, design, and field test plans, and to provide guidance for commercial application of the final product.

In the second stage, field tests of the system at two railroad crossing sites that have significant levels of train and motor vehicle traffic will be conducted. These crossings will be equipped with pulsed LED warning beacons that operate in conjunction with the existing grade crossing signals. Eight school buses will be equipped with devices that detect these pulsed signals and provide the drivers with both audible and visual alarms. The buses will also be equipped with data loggers to record LED signal acquisition and driver response data. Once the field test data have been analyzed, the project evaluation panel will reconvene to review the results and make recommendations for technology transfer, product approval and marketing.

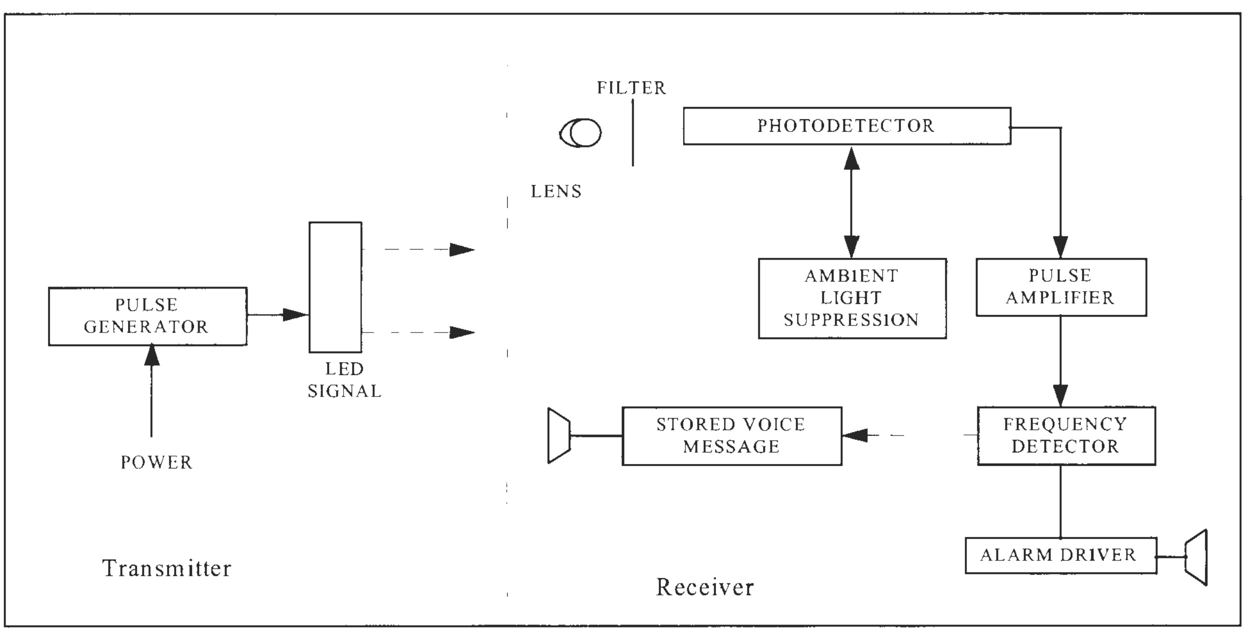


FIGURE 2

System overview.

The contractor is Relume Corporation and the project is scheduled for completion in summer of 2000.

Technical Advisor:
    Bruce George, FRA

Project Panel:
    John Abraham, Traffic Engineer, Troy, MI
    Willard Alroth, Chairman, ITE Grade Crossing Committee
    Mike Coghlan, Transport Canada; John Sharkey, Safetran (Formally with IC RR)

IDEA Contract: $69,000

Cost-Sharing: $15,000

Project Total: $84,000

Start: May 1998

Complete: August 2000

HSR-8: Microwave Train Detection System for Grade Crossings

O'Conner Engineering, Inc. - Benicia, California

IDEA Concept and Product

Despite substantial reductions in accidents at highway-railroad intersections over the past decade, such accidents remain a major cause of fatalities and injuries related to railroad operations. Accordingly, both high-speed and freight railroads, as well as local, state, and federal highway agencies and the Federal Railroad Administration are interested in innovative, low-cost alternatives to conventional grade crossing warning systems. A key component for such systems is the technique for detecting the presence of approaching trains to trigger the activation of warnings such as flashing lights and gates. Conventional systems rely on the shunting of track circuits by approaching trains for such activation. However, track circuits are expensive to install and maintain, and are not always 100% reliable under conditions of rail contamination or light-weight rolling stock. Moreover, as conventional train control systems that use track circuits are replaced by communications-based train control systems, track circuits are expected to be phased out. This has resulted in a search for alternatives to conventional track circuits for train presence detection. The objective of this project is a low-cost, reliable alternative to conventional track circuits for activating grade crossing warning systems that is ready for commercial application and for which there is a significant market potential.

A state-of-the-art microwave system is used to determine the presence, position, velocity, and direction of movement of trains for activation of highway grade crossing warning systems. The ranging sensor uses frequency modulated continuous wave (FMCW) processing for determining the distance of trains from the crossing (within a frequency range of 24.35 to 24.7 GHz), and Doppler processing for measuring train velocity. The ranging sensor has a power output of .005 watts, a range of about 1 mile, and a range resolution of 2 feet. The velocity sensor is a Doppler module radar operating at 24.125 GHz and also has a power output of .005 watts and a range of 1 mile. It is capable of detecting closing or receding velocities from 0.5 mph up to 150 mph.

The system has the potential to monitor train progress continuously to update the train's estimated time of arrival at the crossing. Variations in train speed are therefore compensated for, and a constant advanced warning time can be maintained. The system can also sense when a train has stopped and the warning system should be deactivated.

Project Progress

This IDEA project is being conducted in two stages. During Stage I, O'Conner Engineering completed the development of prototype systems to be used in field tests. A project evaluation panel was convened to review the system design and field test and evaluation plans.

Stage II of the project is now underway. Prototype systems have been installed at crossings on the Kansas City Southern Railroad and the Burlington Northern Santa Fe Railroad. These test sites were selected as being representative of the range of grade crossing operating environments commonly found in the United States. Data are being collected to evaluate such performance measures as range and train speed sensor accuracy, trains missed, false alarm rate, accuracy and consistency of advanced warning time provided, any electromagnetic inter-

FIGURE 1

Microwave range sensor.

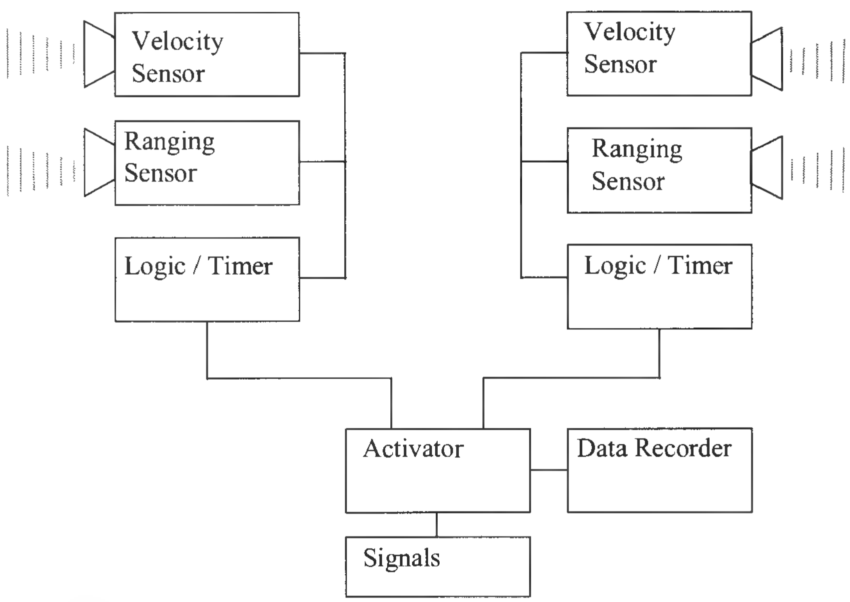


FIGURE 2

Typical track installation block diagram.

ference problems, and fail-safe performance. Event recorders that can be remotely accessed via telephone have been installed at the test sites. These event recorders are dialed up and their data downloaded on a daily basis. The data will enable comparisons between the performance of the prototype system and the conventional track circuit system.

Technical Advisor: Janie Page Blanchard

Project Panel:

Ernest Franke, Southwest Research Institute;
Fred Perry, MPH Industries;
Buck Jones, Kansas City Southern Railroad

IDEA Contract: $78,500

Cost-Sharing: $23,000

Project Total: $101,500

Start: April 1997

Complete: April 2000 (est.)

HSR-9: Folding Arm Extension for Grade Crossing Gates

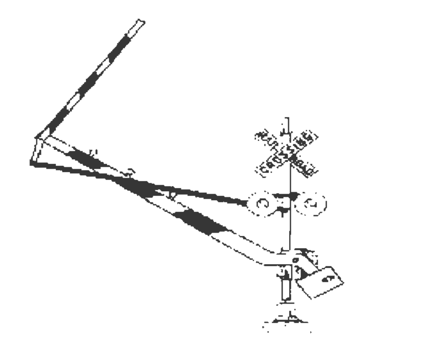
Foster-Miller, Inc., Waltham, Massachusetts

IDEA Concept and Product

A substantial number of accidents at highway-railroad grade crossings are caused by motor vehicles driving around the gates. Drivers become impatient, especially if they cannot see any approaching trains, or if they think they have adequate time to traverse the crossing before the train arrives. One approach for discouraging this risky behavior is gate or barrier systems that block all traffic lanes at the crossing. Four-quadrant gate systems, for example, use conventional gates at the four corners of the crossing and thereby prevent, or at least make it difficult, for drivers to go around the gate arm blocking their lane of traffic.

Application of this concept must address the possibility that vehicles could become trapped on the railroad tracks between the gates. Accordingly, the designs of many of these four-quadrant systems include a delayed activation of the exit gate arm. Some of these systems use sensors to detect the presence of vehicles on the tracks, and will not activate the exit gate until the sensors detect that the tracks are clear. The objective of this project is to develop and field test a low-cost alternative to conventional four-quadrant crossing warning systems to prevent motorists from driving around the gates.

The concept to be investigated is a low-cost modification to existing two-quadrant grade crossing gate arms that extends the arms to cover all four quadrants of the crossing. The extensions will be designed to cover the two crossing entrance quadrants first, and then, after allowing motorists in the crossing to pass, the extensions will be deployed to block the remaining quadrants to prevent unsafe motorist behavior. The extension system includes a sensor to detect the presence of a vehicle on the crossing when the system is activated.



Single Arm Folding Extension (SAFE)

Figure 1

Design concept for single-arm folded extension

Project Progress

This project will be conducted in three stages. The first stage will include a survey of literature and grade crossing warning system technologies, including vehicle sensor technologies. The results will be used to develop the system requirements and design criteria. In the second stage, a prototype system will be fabricated and laboratory tested. The third stage will include field tests at an active crossing, and the analysis of data on performance, reliability, and driver response.

An engineering design for a single-arm folded extension (SAFE) has been completed and a sensor technology for monitoring the grade crossing area has been recommended based on a review of the sensor requirements and the available technologies. A design prototype of the single-arm folded extension was fabricated and tested at Foster-Miller. The prototype was then installed for preliminary testing at a live crossing on the Providence & Worcester Railroad. The project panel reviewed the results of these preliminary tests and recommended modification to the prototype and additional tests. The contractor has initiated discussions with manufacturers regarding licensing and production.

Project Panel:
- Andrew Davis, B&B Manufacturing;
- John Law, Guilford Industries;
- James Sottile, FRA;
- William Watson, Amtrak;
- Lorraine Pacocha, MBTA;
- Bernard Cartier, P&W RR

IDEA Contract: $68,500

Cost-Sharing: $30,500

Project Total: $99,000

Start: November 1998

Complete: April 2000

HSR-10: A Neural Network Video Sensor Application for Railroad Crossing Safety

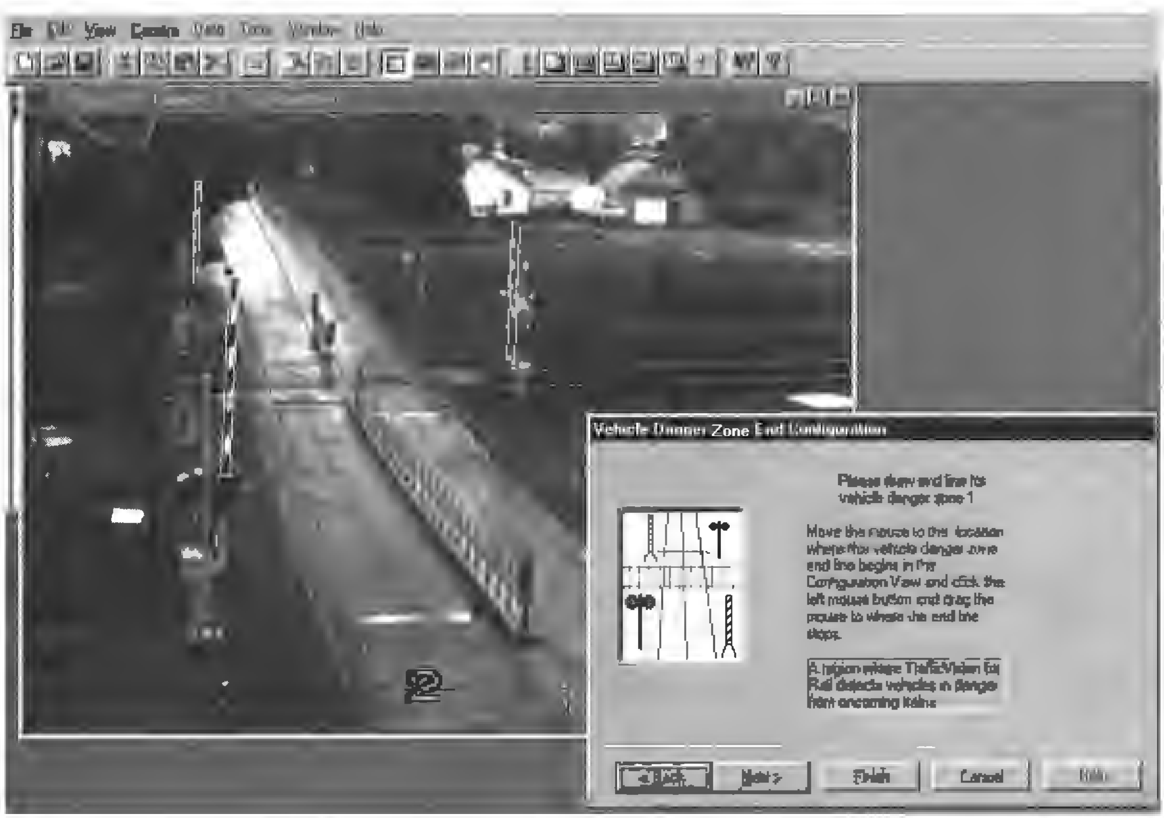
Nestor Corporation, Providence, Rhode Island

IDEA Concept and Product

The introduction of four-quadrant gate systems that block both the entrance and exit of traffic lanes to railroad grade crossings has resulted in the need for information regarding highway vehicles within the crossing area when these systems become activated by approaching trains. In addition, there is a widespread and growing need for a low-cost crossing surveillance system that could be used for such functions as observing motorist behavior at crossings; detecting the presence of pedestrians and bicyclists in the crossing area; the raised, lowered, or altered condition of crossing arms; and the functional status of signal crossing lights.

The objectives of this project are to determine the feasibility of using video for real-time detection of the presence of vehicles and trains at railway grade crossings, and to monitor crossings equipped with gates and signal lights to determine whether these devices are functioning properly.

This IDEA project will develop and test software necessary to implement a video-based grade crossing surveillance system using a neural network-based video detection technology. The neural network must be able to accurately interpret the objects that move across a grade



crossing as well as the condition and functioning of the crossing warning system components. The system could be used for such functions as providing alarm signals to motorists in extreme danger, messages to maintenance personnel regarding damaged or malfunctioning crossing system components, data for assessing grade crossing risk, and enforcement of grade crossing violations.

Project Progress

The first stage of this IDEA project involved the definition of specific functional requirements for an automated video surveillance system for grade crossings. The second stage of the project, which concluded at the end of August 1999, consisted of collecting video of grade crossing activity for the purpose of follow-on software development and demo construction. A library of videotapes of grade crossing activity was collected from 9 different crossings in California, Connecticut, Florida, and Washington. Data was collected from single- and multiple-track crossings, crossings equipped with standard gate arms and flashing lights as well as quad-gate arms. Train traffic at the crossings consisted of freight, passenger, and commuter rail service. Video data was collected at different times of day and under different weather conditions (including snow) in order to represent a variety of visibility conditions under which the video sensor capability could be tested.

The final stage of the project included software development to apply the neural network and other image processing technologies to the interpretation of the grade crossing video data as set forth in the project objectives. User interface functionality has been developed to support the system configuration necessary to interpret a grade crossing scene. Software for vehicle, train, and crossing signalization status detection was developed. Specific technical issues addressed included detection accuracy (e.g., incidence of false negatives and false positives), number and configuration of video cameras required, speed of operation and effects of visibility conditions. A desktop demonstration that can showcase the system was developed as part of the final project deliverable. Following completion of this IDEA contract, the system will be installed at several crossings in Florida under contracts with the Florida DOT and FRA

Technical Advisor:
Ron Ries, FRA

Project Panel:
Bill Browder, Association of American Railroads
Anya Carroll, Principal Investigator, Volpe Transportation Systems Center
Dennis Hamblett, Washington DOT
Anne Brewer, Florida DOT, Administrator of Rail Operations
Haji Jameel, California Public Utilities Commission

IDEA Contract: $ 100,000

Cost-Sharing: $ 117,307

Project Total: $ 217,307

Start: June 1998

Complete: January 2000

HSR-11: Quad Gate Crossing Control System

Rail Safety Engineering - Rochester, New York

IDEA Concept and Product

A major cause of highway-railroad grade crossing accidents is attributed to vehicles driving around the traditional entrance-only crossing gates. As a result, there is great interest in so-called four-quadrant gate systems typically consisting of two pairs of entrance/exit gates providing a complete crossing barrier to prevent drive-around. Existing gate control systems are expensive to modify for four-quadrant gate operation, especially when required to incorporate methods of detecting vehicles stopped on the tracks.

The objective of this IDEA project is a fail-safe, microprocessor-based, application-specific controller that can directly interface to various vehicle detection schemes and will operate exit gate mechanisms and the currently installed entrance gates.

This project developed and tested a four-quadrant gate control system based on a novel programmable controller. The product will be an integrated control system consisting of a simulation-design/verification tool, application-specific vital software generator, and solid state vital quad-gate crossing controller hardware. Existing techniques for on-crossing vehicle detection and approaching train detection will be supported to assure that vehicles will be given sufficient train warning and cannot be trapped within the crossing. A software-based application tool set to assist and streamline the design of individual applications of the controller will also be developed.

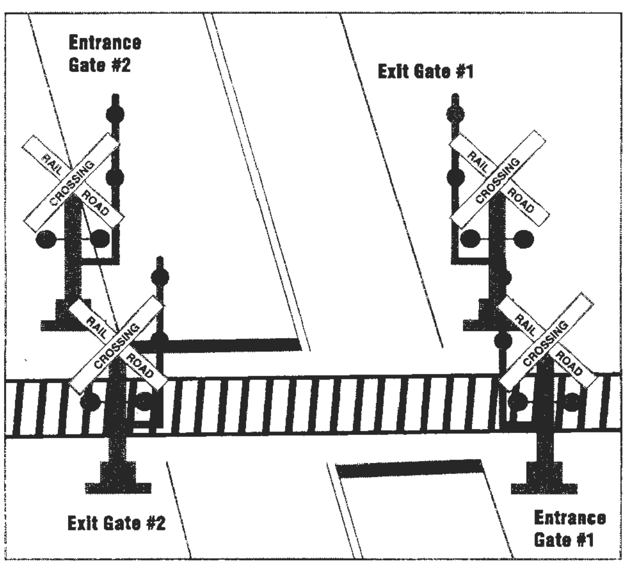


FIGURE 1

Typical four-quadrant gate system.

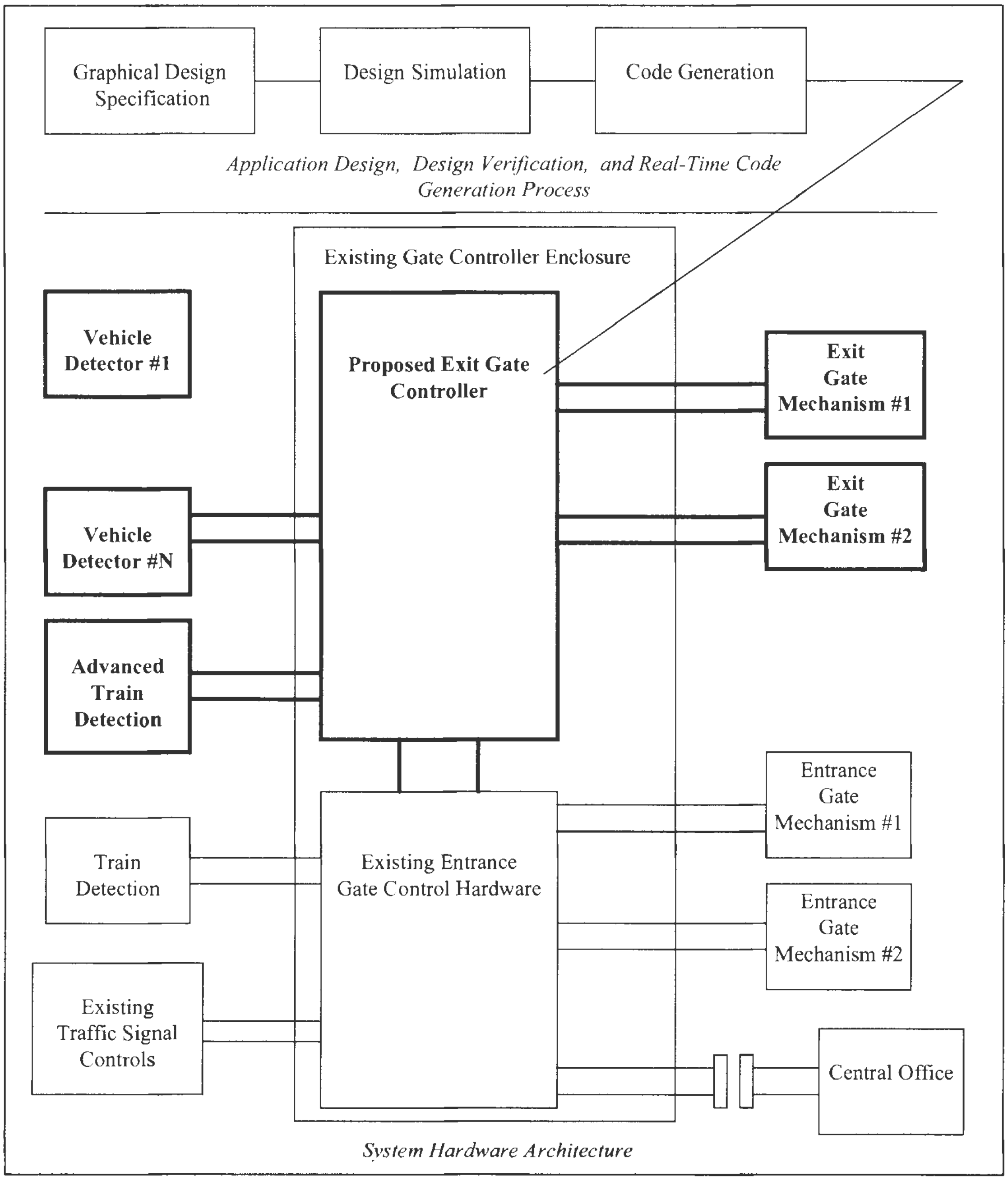


FIGURE 2

Proposed quad-gate crossing system.

Project Progress

The project began with the specification of functional and system requirements based on input from potential users of quad gate crossings. The results were used to develop a high-level system design. Project objectives, approach, and the functional requirements were reviewed by a panel of experts. An external interface specification was completed to describe the interface with the WaveBand radar crossing surveillance system (See HSR-13). The quad-gate controller will be based on a GE-Fanuc Series 90-30 programmable controller. Software requirement specifications and detailed designs have been completed. A prototype system has been fabricated and laboratory tested. The prototype system will be field-tested at an active crossing, and the test data analyzed to assess performance and reliability. Field testing will be conducted in early 2000.

Technical Advisor:
Dr. Fred Coleman, University of Illinois

Project Panel:
Dr. Fred Coleman (Chair);
Mr. Richard McDonough, NYDOT

IDEA Contract: $95,000

Cost-Sharing: $139,000

Project Total: $234,000

Start: September 1998

Complete: May 2000 (est)

HSR-12
Fiber-Optic Radar System for Track Obstacle Detection

Aspen Systems – Marlborough, Massachusetts

IDEA Concept and Product

Railroads occasionally use electric fences along their right of way in remote areas where there is a danger of rock, snow, or mud slides obstructing the track. If the fence is broken, it activates the signal system and alerts the dispatch center. Terrain where these risks are prevalent usually contain sharp curves that prevent train crews from detecting the obstructions in time to stop. These fences are not always reliable or completely effective for detecting obstacles on the tracks. For example, snow or mud slides may not always break the fence, large boulders have been known to skip over these fences, and in some territories large animals can break such fences, triggering a false alarm.

The objective of this project is to develop and demonstrate a system using fiber-optic laser radar technology to detect obstacles along the railroad right of way and communicate this information either directly to the crew of approaching trains or to the dispatch centers. The fiber-optic radar system, shown in Figure 1, is constantly monitoring a track region in order to provide early warning to trains such that they can be stopped in time and track maintenance personnel can take corrective action.

A wayside transceiver launches six laser radar beams into the air path just above the track, which are reflected back to the transceiver for processing. In the event an obstacle is present on the track, some or all the pulses would not be received, thereby triggering an alarm signal. An illustration of detecting an obstacle, along with the received signals for obstacle detection is shown in Figure 2.

Project Progress

The initial stage of the project included a survey of railroad personnel to establish functional requirements for the fiber-optic laser radar system. A signal processor has been developed that analyzes return pulses and makes a decision establishing the presence (or absence) of a

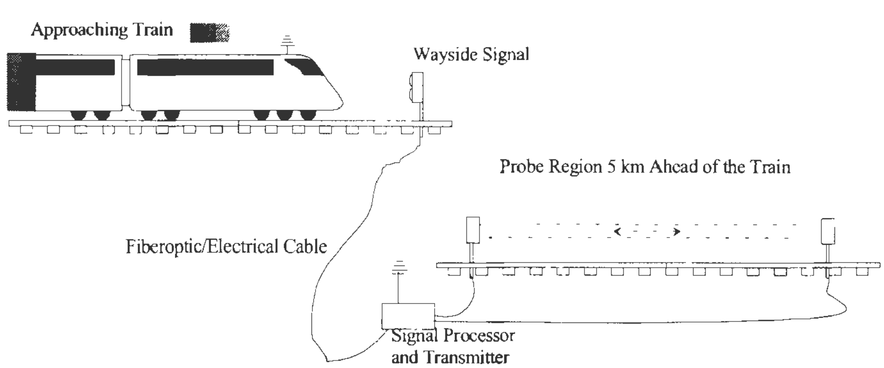


Figure 1.

System overview of the fiber-optic laser radar system for track obstacle detection

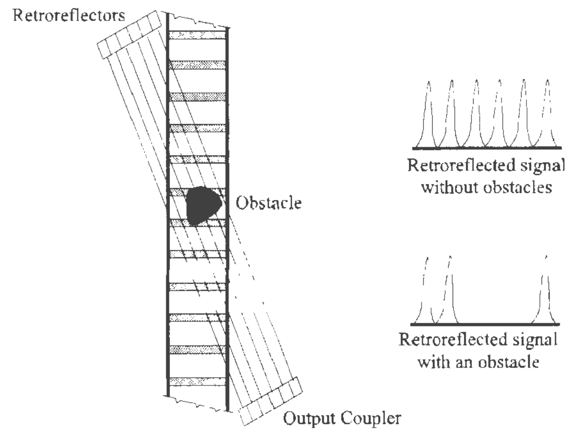


Fig. 2

Schematic of obstacle detection and received signals

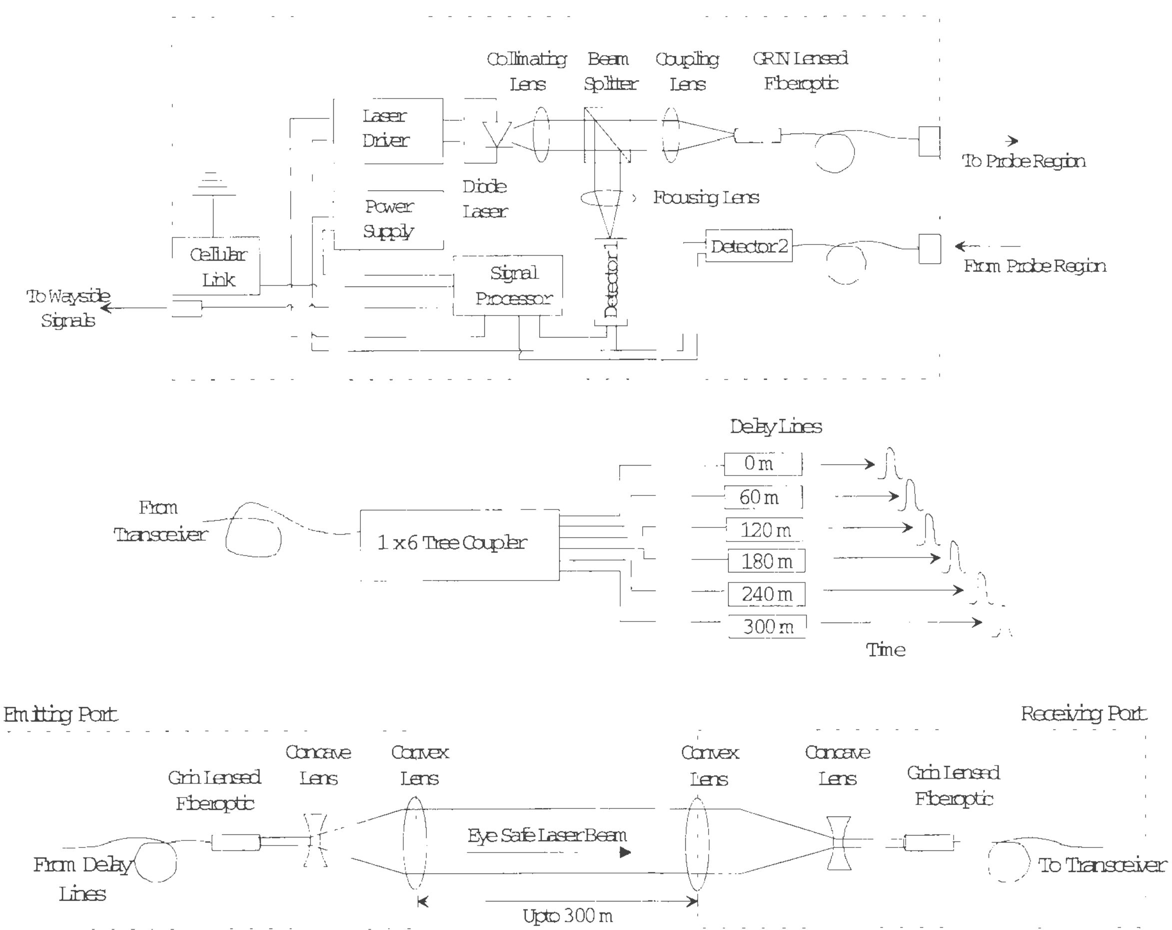


Figure 3.

Individual building blocks of the fiber-optic laser radar for track obstacle detection.

hazardous obstacle. If an obstacle is detected, the system transmits a warning message to the wayside signals and/or the dispatch center. Figure 3 shows the individual building blocks of the system in detail.

Currently, talks are underway with a railroad company that has expressed interest in participating in the field implementation and testing phase of this project. Test results will be used to develop upgrades for a pre-market design. The final report will include results of the survey, laboratory experiments, field tests in a railroad operating environment, and analysis of test data.

Technical Advisor:
Bill Thompson, Union Pacific Railroad

IDEA Contract: $93,000

Project Total: $93,000

Start: March 1998

Complete: December 1999 (est.)

HSR-13:
Grade Crossing Obstacle Detection Radar

WaveBand Corporation - Torrance, California

IDEA Concept and Product

There is growing interest in the use of four-quadrant gate systems at railroad grade crossings to prevent motorists from driving around gate arms that block only the entrance lanes to crossings. The introduction of four-quadrant gate systems that block both the entrance and exit of traffic lanes across railroad tracks (see Figure 1) has resulted in the investigation of technologies to provide information regarding highway vehicles within the crossing area when these systems become activated by approaching trains. Such systems could detect vehicles on the tracks for timing the activation of the exit gate to avoid trapping vehicles between the gates.

The objective of this project is to determine the feasibility of using a millimeter wave (MMW) radar system for detection of highway vehicles within grade crossings. The sensor system would be designed to provide a standard interface with four-quadrant control systems for intrusion detection and sequencing the activation of the exit gates.

WaveBand Corporation has developed a novel scanning millimeter wave radar antenna system. This system has the potential for use in detecting intrusions in grade crossing areas for automated sequencing of multiple gate arms such as four-quadrant gate systems. The system uses a spinning grating antenna. The narrow-beam scanning antenna provides the spatial resolution required for obstacle detection at railroad crossings. Since the system operates in the MMW frequency band, it should be able to detect objects in adverse weather conditions. The project should result in a product that can interface with four-quadrant gate controllers to provide data on vehicle presence in the crossing necessary to sequence gate operation.

Project Progress

The current project (HSR-13) is a follow-on to a previous IDEA project (HSR-1) to investigate the concept of a spinning grating millimeter wave scanning antenna for application to railroad and automotive obstacle detection and collision avoidance (see Figure 2). The project began with the collection and analysis of information from current and potential users of crossing

Figure 1

Typical 4-quadrant gate

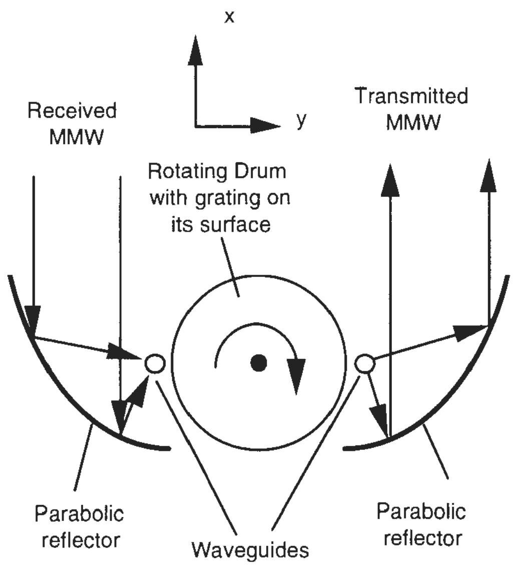


FIGURE 2

Spinning grating antenna

gates, including four-quadrant gate systems, to develop functional and design specifications for intrusion detection. A project advisory panel of experts reviewed the objectives, functional and design specifications, and test plans. Design and fabrication of the system hardware and software was then completed. The next steps included laboratory shakedown tests followed by field testing at an active grade crossing.

Technical Advisor:
Dr. Fred Coleman, University of Illinois.

Project Panel:
Dr. Fred Coleman (chair);
Mr. Richard McDonough, NY DOT.

IDEA Contract: $92,123

Project Total: $92,123

Start: March 1998

Complete: February 2000 (est)

HSR-14:
Multiple Sensor Inertial Measurement System for Locomotive Navigation

Ensco, Inc. - Cocoa Beach, Florida

IDEA Concept and Product

There is growing interest and activity among railroads, suppliers, and government agencies in the development of communications-based train control systems. These systems rely on sophisticated computers on board locomotives and at central train control centers, combined with train location and navigation systems, and digital data communications links for the control of train operations (see Figure 1). They have the potential to dramatically increase the utilization of railroad track and equipment and improve safety and service reliability. These systems would replace the conventional track-circuit-based signal systems and thereby allow safe operations with much shorter headways between trains to improve system throughput and increase track capacity. They would also enable the monitoring of train crews for compliance with computer-generated train movement authorities using the on-board computers and enforce compliance with automatic brake applications if these authorities are violated.

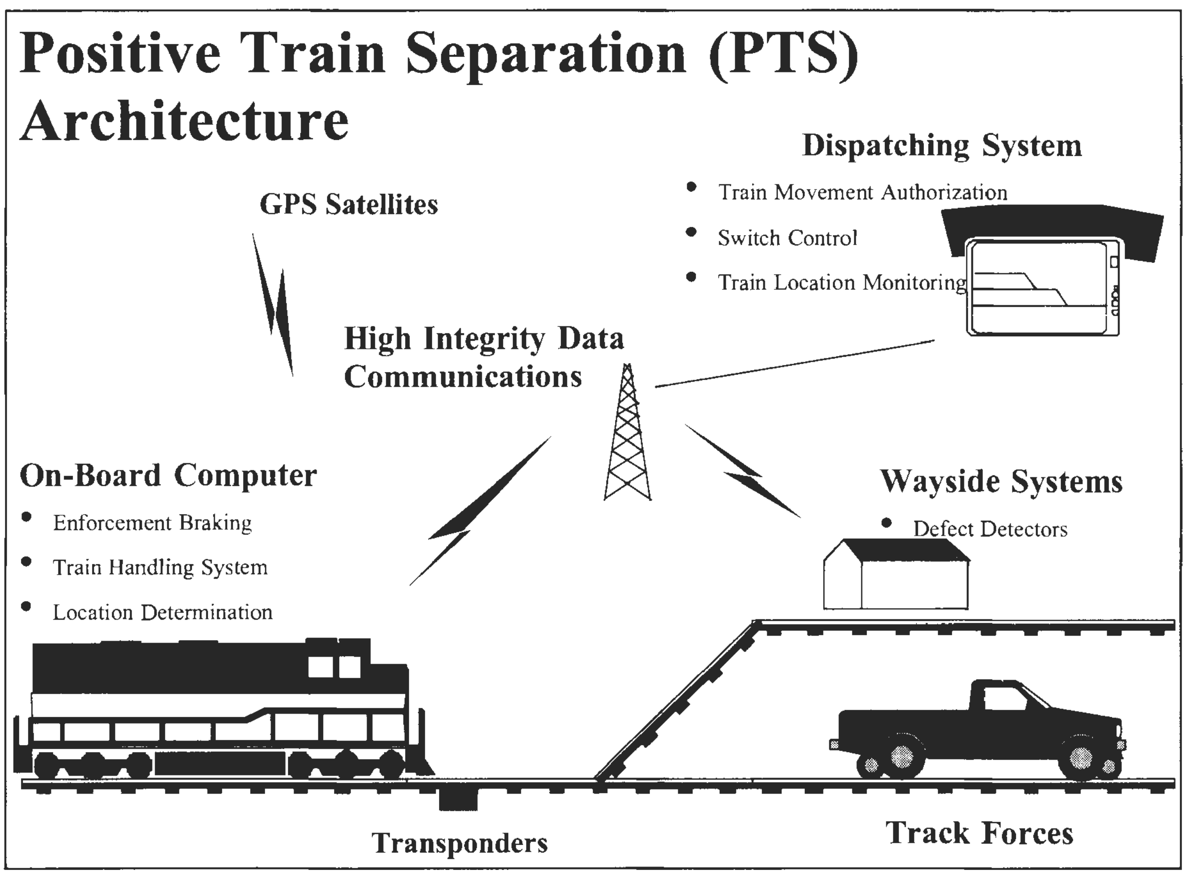


FIGURE 1

Positive Train Separation (PTS) architecture.

A key component of such systems is the locomotive navigation system. In order for the computer system to determine whether the train is in compliance with movement authorities, precise, real-time train location data is required, including identification of which track the train is on. GPS or DGPS alone does not provide the accuracy required, as trains often operate in multiple-track territory with track centers as close as 13 feet. Accordingly, there is a need for a low-cost alternative to conventional rate gyros or laser fiber optic gyros for precise navigation.

The objective of this project is to investigate the use of micro-electromechanical systems (MEMS) accelerometer arrays, combined with GPS, to provide the accurate location of locomotives.

This project examines the possibility of using an array of inexpensive MEMS accelerometers and integrating the accelerometer data with GPS or DGPS data using Kalman filtering techniques instead of the more expensive conventional accelerometers and gyros for locomotive navigation.

Project Progress

In the first stage of this project the system requirements, initial system architecture, and navigation and Kalman filtering algorithms were developed. Alternative sensor technology was evaluated, and sensors were selected. The sensor system was designed and the system configuration was optimized. In the second stage, a laboratory inertial system using MEMS accelerometers and micromachined gyros was developed and evaluated. Software was developed for navigation and filtering. During the third stage, an inertial navigation system consisting of four 3-axis MEMS accelerometer modules was installed on the Amtrak 10002 Track Geometry Car and field-tested on the high-speed Washington-to-New-York Metroliner run. The test recorded data from the field navigation system, the laboratory inertial system, and independent higher-resolution sensors. The test data indicate that this system has the potential to

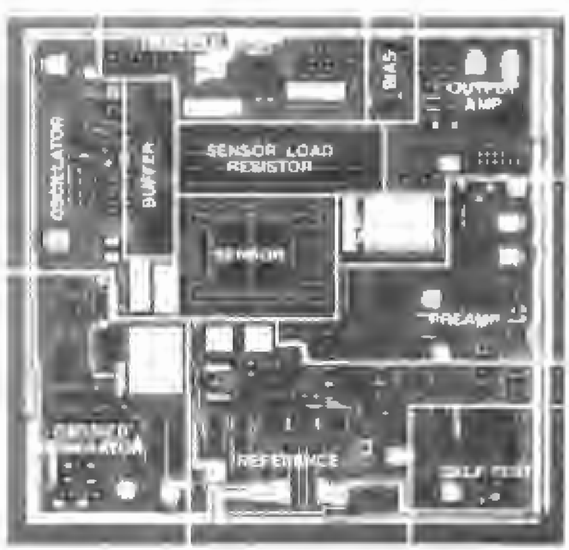


FIGURE 2

Accelerometer using MEMS technology. The accelerometer sensor is in the center, surrounded by support circuitry. The entire system is on a silicon chip 0.11 inches wide.

provide a low-cost alternative to conventional accelerometers and gyros for locomotive navigation. A final project panel meeting was held in October 1999 to review the test results and discuss the next steps toward implementation.

Technical Advisor:
Denny Lengyel, ARINC

Project Panel:
Lt. Laura Kelly, USAF;
Ron Lindsey, CSX;
Bill Matheson, GE-Harris;
Bill Petit, Safetran;
Gerhard Thelen, NS

IDEA Contract: $84,961

Cost sharing: $19,865

Project Total: $104,826

Start: June 1998

Complete: February 2000 (est)

HSR-15: Hybrid Uni-Axial Strain Transducer

University of Utah

IDEA Concept and Product

The collection and analysis of data on the fatigue history of high-speed railroad components such as rail, bridge members, and wheels is extremely difficult using traditional data acquisition systems. Strain-gauge systems typically require massive signal processing devices, power sources, wiring, etc., and these systems are not durable. A uni-axial strain transducer (UAST) is a micro-electromechanical system (MEMS) with such characteristics as high resolution and high sampling rate, absolute encoding, no calibration requirements, no drift over time, and less measurement noise than analog-based strain sensors. The UAST exploits the capacitive coupling between an array of electrostatic field emitters and an array of 64 field detectors on a CMOS chip. The slightly different array element spacings form a vernier scale and digital signal processing of the detector outputs is used to calculate the displacement of the emitter array relative to the CMOS detector chip. Displacements of down to 2.5 nanometers can be resolved. The sensor sampling rate is dynamically configurable and up to 128 UASTs can be linked on a common 5-wire digital bus, eliminating the need for shielding and considerably reducing the number of wires which will have to be routed through the structure to be measured. Because a Hybrid UAST has low DC power requirements, it can be used in remote locations. The small size and on-chip signal processing features will make a Hybrid UAST a truly portable testing device.

The objective of the proposed research is to determine the potential of the Hybrid UAST as a new tool to continuously monitor, analyze, and store the strain history of components such as rail. This data can be periodically downloaded and used for such purposes as measuring rail stress induced by axle loadings or thermal loadings. The research is to develop a prototype Hybrid UAST, which includes nonvolatile RAM to store strain cycling history, e.g., tracking how many times the UAST crosses each of specified strain thresholds across its dynamic range, and temporarily storing the preprocessed data. The prototype Hybrid UAST consists of three parts, a UAST sensor, a networking controller box, and a communication cable. Figure 1 shows a schematic design of a Hybrid UAST controller to be operated by a battery. A load cycle counting algorithm is integrated into a microcontroller, which is programmable using configuration switches. Using this Hybrid UAST controller, eight different strain levels can be collected at four different sampling rates.

Project Progress

Laboratory tests using an aluminum beam equipped with UASTs and conventional foil strain gauges demonstrated the accuracy and repeatability of the UASTs. A series of cyclic loading tests was performed to simulate a moving trainload applied on a rail using an MTS loading machine in the laboratory. The main purpose was to determine an optimum sampling rate for rail. An optimum technique for mounting the HUAST to rail has been developed. A project panel meeting was held to review the project objectives and approach. A prototype HUAST design and load cycle counting algorithm have been developed and tested using actual HUAST strain data taken from a rail section at a field test site in Salt Lake City. A prototype HUAST

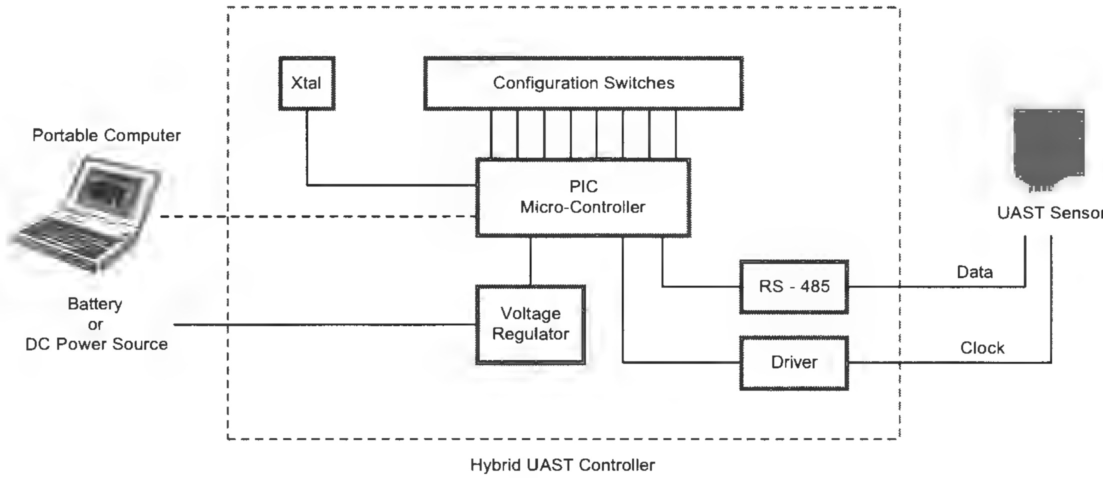


Figure 1.

Schematic diagram of a prototype Hybrid UAST

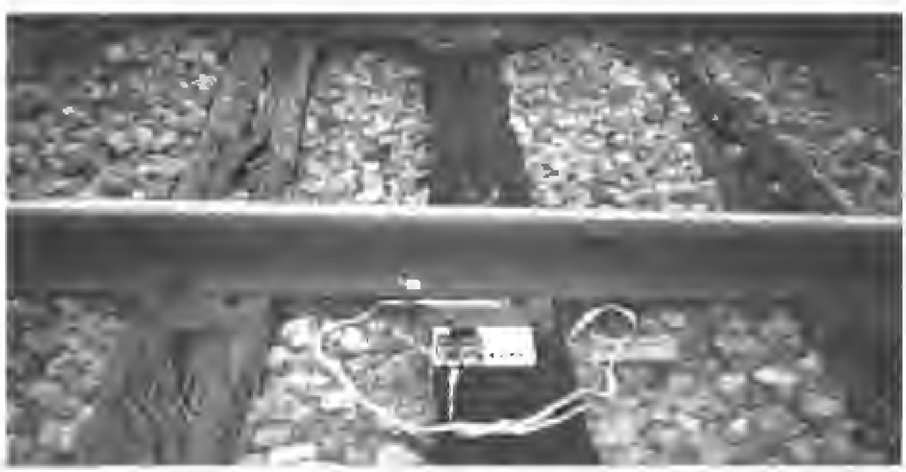


Figure 2.

Strain data collection from a rail using UAST™ and a microcontroller

package suitable for field application was fabricated and laboratory tested. Field testing of the HUAST prototype package in a rail operating environment was conducted, and analysis of the test data has been completed. Remaining tasks include a project panel meeting to review the test data and draft final report.

Technical Advisor:
James Lundgren, Transportation Technology Center, Inc.

Project Panel:
David Warnock, Utah Transit Authority;
Crosby Mecham, Utah Transit Authority;
Rick Campagna, Utah Department of Transportation

IDEA Contract: $45,000

Cost Sharing: $20,000

Project Total: $65,000

Start: November 1998

Complete: February 2000 (est.)

HSR-16: Advanced Intersection Controller Response to Railroad Preemption

Texas Transportation Institute – College Station, Texas

IDEA Concept and Product

Traffic signals that are located near railroad-highway grade crossings are designed to permit vehicles that may be stopped on the tracks to move to safety when a train approaches the crossing. In some cases, the warning time provided to the traffic signal system is as little as 20 seconds before the train arrives at the crossing. Often, the short duration of this warning time can cause crossings to operate in a potentially unsafe and inefficient manner. Further, existing standards, primarily the *Manual on Uniform Traffic Control Devices* (MUTCD), allow traffic signal controllers to cut short the pedestrian phases and vehicle phases that conflict with the track clearance phase. Such heavy-handed preemption treatment, while effective at arriving at the track clearance phase, may leave pedestrians with curtailed WALK and/or flashing DON'T WALK indications while they are crossing the street (see Figure 1), and it may lead to short and confusing signal indications for motorists. This project will develop a new method for controller treatment of railroad preemption calls that is based on advanced train detection and controller notification. Detection and preemption systems that are in use today will remain as a fail-safe preemption treatment that follows the new strategy, known as the transitional preemption strategy (TPS).

The TPS logic developed and refined during this research offers a strategic and reliable method for providing improved intersection controller response to the preemption of adjacent highway-rail grade crossings. TPS will ensure that phases that conflict with the track-clearance phase receive the minimum time required for vehicles and pedestrians to clear the intersection; if such time is not available, the phases will never be initiated. The smooth transition into intersection phases that clear vehicles from the highway-rail grade crossing is made possible by advanced detection and warning of the arrival of an approaching train. The TPS uses this advanced warning information to most appropriately respond to the preemption call. Placement of the advanced warning devices is such that the controller is able to provide the necessary minimum times for both pedestrians and vehicles on phases that conflict with the track-clearance phase before it is initiated. The end result of using the TPS is improved intersection and grade crossing safety. The fact that TPS avoids the display of short green indications for motorists at the intersection can also lead to operational improvements in terms of the intersection's ability to smoothly and safely process vehicles.

Project Progress

Development of the TPS logic during this IDEA project has been organized into three stages. During Stage I, researchers at the Texas Transportation Institute (TTI) synthesized background research and current practice pertaining to railroad preemption of traffic signals near highway-rail grade crossings. Once this was completed, the TPS logic algorithm was developed.

Stage II of the research had as its primary objective the simulation testing of the TPS logic. The TPS algorithm has been software encoded and integrated into a unique simulation and testing environment with the staff support and hardware of TTI's TransLink® research laboratory. The testing environment, known as hardware-in-the-loop simulation, allows a traffic

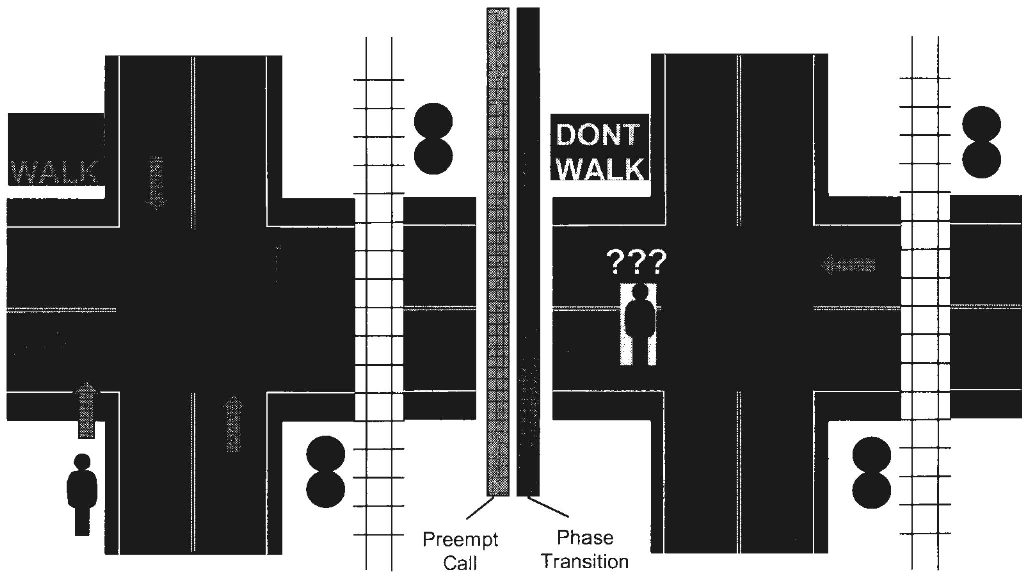


FIGURE 1.

Standard preemption scenario illustrating MUTCD pedestrian "relative hazard" position

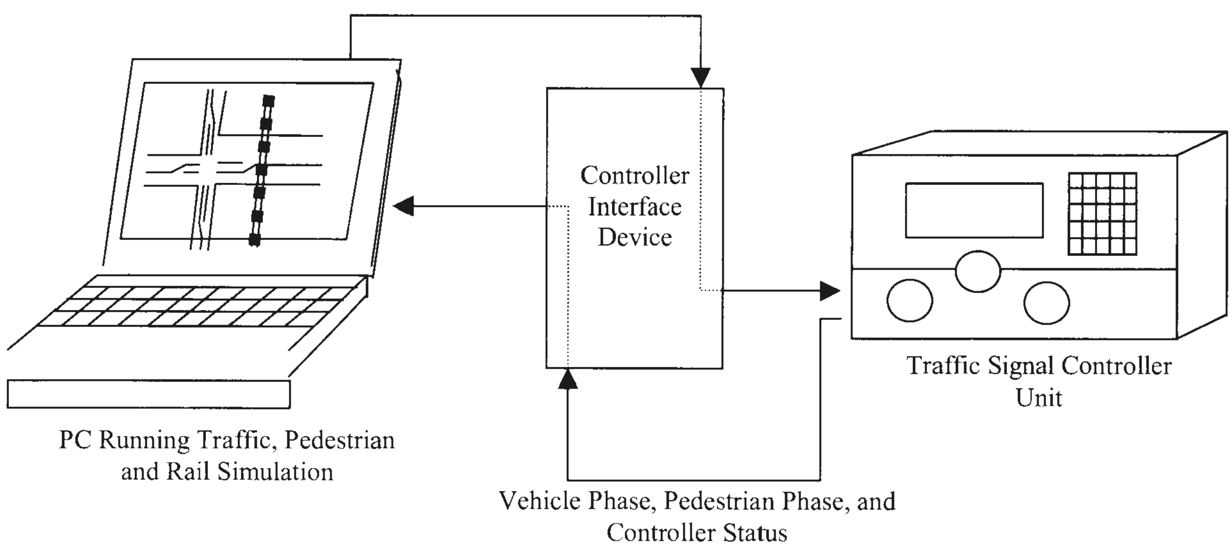


FIGURE 2.

Simulation environment for transitional preemption strategy development and testing and/or traffic and highway-rail grade crossing simulator to be connected to an actual traffic signal controller device. A piece of electronic hardware known as a controller interface device connects to the controller's standard input/output connectors and to a PC's USB port, allowing the use of the traffic signal controller's functionality for traffic control and preemption for vehicle, pedestrians, and trains simulated on the PC. During the testing and simulation stage, the logic has been refined and improved. The results of the simulation effort included a side-by-side comparison of results from cases that did and did not include the TPS logic.

Stage III of the project, which included field-testing of the algorithm at a signalized intersection adjacent to a grade crossing, has been completed. Advanced train detection information at the field site was obtained using TTI TransLink's Doppler train-detection equipment and train arrival-time estimation software.

Technical Advisor:
Hoy Richards, Richards and Associates

Project Panel:
Cliff Shoemaker, Union Pacific Railroad;
Arnold McLaughlin, Eagle Traffic Control Systems;
Mark Smith, City of College Station, Texas.

IDEA Contract: $65,000

Cost-Sharing: $15,310

Project Total: $80,310

Start: February 1999

Complete: February 2000 (est.)

HSR-17:
Automatic Warning System for Track Maintenance Workers

Raven, Inc. - Alexandria, Virginia

IDEA Concept and Product

The safety of track maintenance workers is a vital concern, especially where high-speed trains are operating. These maintenance workers must often rely on a so-called flagman or watchman who is assigned the responsibility of watching for approaching trains, and alerting workers in time to clear all personnel and equipment from the right-of-way before the arrival of trains. This technique is labor intensive and not always effective. Occasionally, those assigned the job of spotting trains do not see them in time to provide adequate warnings. This can, and does, result in fatal accidents and untold near collisions.

As a result of this concern, there is a need to develop a low-cost, reliable, automatic system to provide effective warnings to track workers of approaching trains.

The concept on which this project is based is the detection of train-induced rail vibrations to activate a warning system for track maintenance workers. The effectiveness of this technology for train detection was demonstrated in a previous IDEA project (HSR-4). This follow-on project is to develop a warning system that combines the moving train sensor with a robotic signaling and train stop device. Initial application would be designed for rail transit applications such as on the Chicago Transit Authority (CTA). Currently, a "slow zone" is established at a track maintenance work site, and a "trip staff" that will automatically stop the train is installed on the tracks. When a train approaches the "slow zone" the flagman sounds a horn to alert the track workers that a train has entered the zone, and signals the train operator to halt with a flag or light. After receiving a track-clear signal from the foreman, the flagman removes the trip staff and signals the train to proceed.

This project will develop and test a robotic signaling device to replace the flagman (Figure 1). It will use rail vibration technology to detect the presence and speed of trains approaching track maintenance work zones. The robot will be capable of placing and removing the trip staff, and will be under the control of the track maintenance foreman by means of a hand-held device with a radio frequency link to the robot.

Project Progress

The project panel met to review the project objectives, approach, design specifications, and implementation issues. Based on this meeting and meetings with CTA, the prototype design drawings for all of the mechanical assemblies have been completed. Initial measurements of the acoustic signatures in the rails of approaching trains have been analyzed to distinguish between trains and background noise from other sources. The next steps will be the fabrication and preliminary testing of the design prototype. The final stage will consist of operational testing and evaluation of the prototype on the CTA, and an evaluation of the potential of the concept for high-speed rail applications.

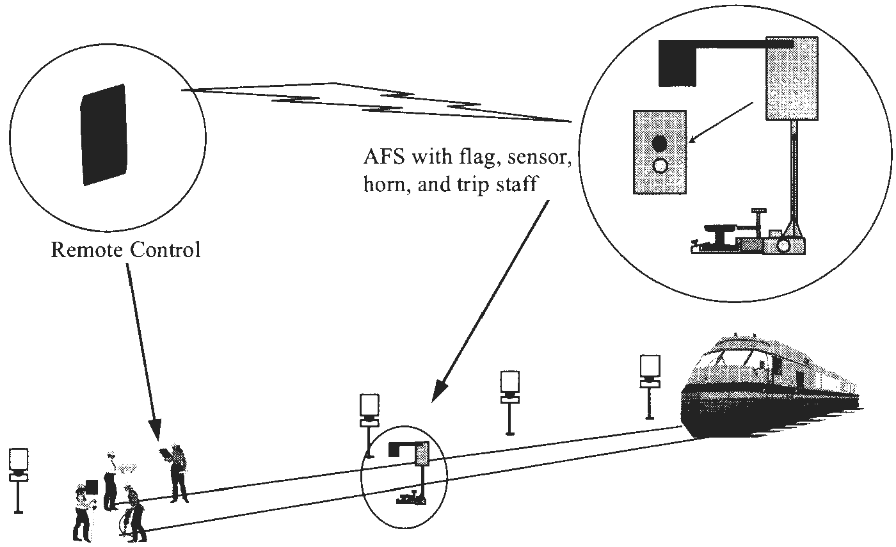


FIGURE 1.

Transit slow zone with automatic flagging system

Preliminary work also includes examination of the need for any regulatory relief that may be necessary for full implementation of such systems. Work on the prototype fabrication is underway, as are preparations for the operational tests. The contractor, Raven, Inc., has been discussing a partnership with a major railroad supplier regarding marketing the final product.

Technical Advisor:
    Howard Moody, AAR

Project Panel:
    Christopher Schulte, FRA;
    Bea Hicks, WMATA;
    Alan Lindsey, BNSF

IDEA Contract: $80,000

Cost-Sharing: $202,000

Project Total: $282,000

Start: October 1998

Complete: May 2000 (est)

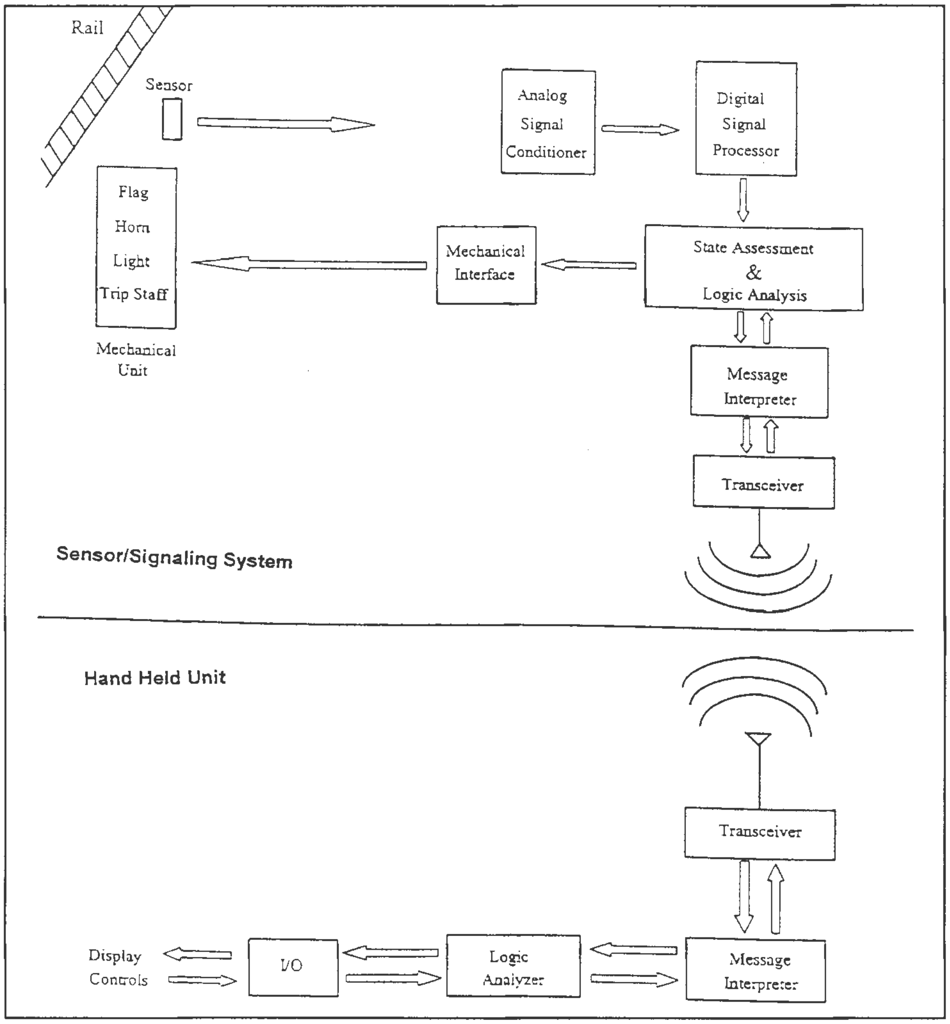


FIGURE 2.

Overview of system concept

HSR-18: An Investigation into the Use of Buried Fiber-Optic Filament to Detect Trains and Broken Rail

Texas Transportation Institute - College Station, Texas

IDEA Concept and Product

For decades, railroads have relied on track circuits to detect train presence and broken rails. However, track circuitry is expensive to maintain, and does not always reliably detect trains due to such factors as contamination at the wheel-rail interface. Moreover, a substantial percentage of rail breaks occur in which electrical continuity is maintained, and are therefore not detected by the track circuits. This research is investigating the feasibility of using fiber-optic filaments buried along the right-of-way to detect trains and broken rail. The approach is to use coherent optical time-domain reflectometry (C-OTDR) in concert with advanced signal-processing techniques and neural networks in buried fiber-optic filaments to detect and locate trains and the ballistic event characteristic of rails breaking under stress.

An optical transmission through a continuous length of low-loss, telecommunications-grade fiber buried along the right-of-way, yet away from track maintenance operations, holds promise for providing an inexpensive, reliable alternative to conventional track circuitry for train presence and broken rail detection. Another potential advantage is that buried fiber-optic filament is free of the problems associated with the electromagnetic interference encountered with track circuits. The objective of this project is a low-cost, reliable alternative to conventional track circuits for near real-time detection and location of rail break events, as well as detection and location of moving trains that can be commercially developed for application to the railroad. If successful, this technology could also facilitate the railroad industry movement toward communications-based train control systems and away from track-circuit dependent train control.

A state-of-the-art coherent laser is used to pulse a buried communications-grade optical fiber. Information is extracted from polarization shift in the laser pulse backscatter light to establish train presence and rail break events as well as the location and time of events. The laser employs coherent continuous waves with a line width of approximately 10 kilohertz. The laser beam is pulsed at 30 nanoseconds over a 0.1 millisecond period to provide a 2-meter resolution in a 20-kilometer fiber length. The system will recognize that a train has stopped by registering the cessation of activity at the last known location.

The system has the potential to continuously monitor train presence, direction, and location while monitoring the track structure for rail breaks. Additionally, the system has the potential to detect and discriminate among various in-train defects, e.g., flat wheels, dragging equipment, and stuck brakes.

Project Progress

This IDEA project is being conducted in three stages. During Stage I, Texas Transportation Institute (TTI) completed the construction of the coherent laser system and demonstrated the principal of detecting very low-energy perturbations on single-mode fiber. The project panel met and reviewed the system design and the field data acquisition and data analysis development plans.

Stage II of the project is now under way. TTI is working in cooperation with Union Pacific Railroad to install and monitor several short test lengths of fiber buried at different depths for data gathering purposes. These data will be used by the software development team to identify train presence and in-train perturbations. The design and fabrication of a rail tensile stress and fracturing apparatus will be completed in this stage of the project. TTI is working cooperatively with Burlington Northern Santa Fe Railway to obtain and install a typical 39-foot panel of track for the tensile stress and fracturing apparatus.

Data from laboratory rail fracture events will be analyzed in Stage III. A fiber-optic filament will be buried according to the work carried out in Stage II. Multiple fracture events will be conducted to develop a representative data base for the software development team to build a sufficiently robust rail fracture recognition program. Stage III of the project is scheduled to be completed in July 2000.

Project Panel:

Henry Lees, Burlington Northern Santa Fe Railway;
James Lundgren, Transportation Technology Center, Inc.;
William Petit, Safetran Systems, Inc.

IDEA Contract: $75,000

Cost Sharing: $47,000

Project Total: $122,000

Start: February 1999

Complete: August 2000 (est)

The Transportation Research Board is a unit of the National Research Council, a private, nonprofit institution that provides independent advice on scientific and technical issues under a congressional charter and the operating arm of the National Academies.

The mission of the Transportation Research Board is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research findings. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academies are a nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by Congress in 1863, the National Academies have a mandate that requires them to advise the federal government on scientific and technical matters.

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY PRESS
Washington, DC 1999

Transportation Research Board
National Research Council
...onstitution Avenue, N.W.
...gton, D.C. 20418

...s Correction Requested

Non Profit Org
US Postage
PAID
Washington, DC
Permit # 8970

S8 P5
MR KEITH L KILLOUGH (007168-00)
DEPUTY EXECUTIVE OFFICER
LOS ANGELES COUNTY MTA
MS 99-23-7
1 GATEWAY PLZ
LOS ANGELES CA 90012-2952