TRANSPORTATION RESEARCH
CIRCULAR

Number 387, January 1992

TRANSPORTATION RESEARCH BOARD LIBRARY
JAN - 8 1992
C.3

Research Problem Statements

Safety Factors Related to High-Speed Rail and Maglev Passenger Systems

TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL

TRANSPORTATION
RESEARCH
CIRCULAR

Number 387, January 1992
ISSN 0097-8515

WORKSHOP ON SAFETY FACTORS RELATED TO HIGH-SPEED RAIL AND MAGLEV PASSENGER SYSTEMS

STEERING COMMITTEE
Robert B. Watson, Chairman

Kenneth W. Addison
Charles J. Engelhardt
William J. Matthews
Paul Taylor
John A. Bachman
William J. Harris
Myles B. Mitchell
William W. Dickhart, III
Richard P. Howell
Charles H. Smith

Liaison Member: Thomas D. Schultz, Federal Railroad Administration

Transportation Research Board Staff: Elaine King

Subscriber Category
VII rail

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

The Transportation Research Board is a unit of the National Research Council, which serves as an independent advisor to the federal government on scientific and technical questions of national importance. The Research Council, jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, brings the resources of the entire technical community to bear on national problems through its volunteer advisory committees.

TRANSPORTATION RESEARCH BOARD LIBRARY
JAN - 8 1992
C.3

PREFACE

The research problem statements included in this circular were generated at the Workshop on Safety Factors Related to High-Speed Rail and Maglev Passenger Systems, which was conducted at the request of the Federal Railroad Administration (FRA). The purpose of the workshop was to identify safety factors related to both of these technologies that require additional research before FRA develops appropriate safety regulations for high-speed rail and magnetic levitation (maglev) systems. FRA and TRB jointly sponsored this workshop, held in St. Louis, Missouri, in April 1991.

FRA has statutory responsibility to ensure the safe operations of intercity high-speed rail and maglev systems, but its existing regulations govern conventional rail systems and do not address many unique features of high-speed rail and maglev systems. The major topics addressed at the workshop were system design criteria and operations; signal, control, and power supply systems; high-speed rail track structure and maglev guideway; and vehicles. Experts in a number of technical areas under these broad topics addressed the workshop attendees, who then divided into working groups to identify research needs. The working groups prepared approximately 70 research problem statements, which are included here. These statements will provide input for the National Maglev Initiative Research Program and for the development of FRA's high-speed rail safety research agenda.

In order to retain the sense and spirit of the workshop participants' efforts, the content of this document has not undergone a comprehensive editing process. Thus, there are areas of redundancy among the various topics and of similar thought between the maglev and high-speed rail technologies. Furthermore, there has been no attempt to prioritize or further refine the workshop's output. The research problem statements as presented herein have been, as far as possible, transferred directly from the notes of the workshop session topic leaders and participants.

The steering committee acknowledges and thanks all the workshop participants for the effort they put into preparing these statements. A list of all workshop participants is included in Appendix A.

ACKNOWLEDGMENTS

The success of the Workshop on Safety Factors Related to High-Speed Rail and Maglev Passenger Systems resulted from the combined efforts of a number of individuals who volunteered their time to serve a variety of functions. Recognition is given to the plenary session leaders: Thomas D. Schultz, Federal Railroad Administration; Charles H. Smith, Florida High Speed Rail Transportation Commission; Tony R. Eastham, Queen's University; Myles B. Mitchell, M. B. Mitchell & Associates, Inc; and Joseph Vranich, High Speed Rail Association. Special recognition is given to the topic leaders who lead the working group discussions and took responsibility for preparation of the research problem statements developed by each of their respective groups. These topic leaders were Paul Taylor, California-Nevada Super Speed Ground Transportation Commission/DKS Associates; Satoru Ozawa, Japanese Railways; Michael Proise, Grumman Corporation; William W. Dickhart, Trans-Rapid International; Jay Anema, Boeing Commercial Airplanes; Arne Bang, Federal Railroad Administration; William T. Hathaway, Volpe National Transportation Systems Center; Herbert Weinstock, Volpe National Transportation Systems Center; P. J. Willis, National Railroad Passenger Corporation; John A. Bachman, Louis Berger International; Donald L. Lindsey, Brotherhood of Locomotive Engineers; Robert M. Dorer, Volpe National Transportation Systems Center; Edward L. Butt, Burlington Northern Railroad; Howard G. Moody, Association of American Railroads; Raymond A. Wlodyka, Volpe National Transportation Systems Center; Imre Gyuk, Department of Energy; Richard D. Johnson, National Railroad Passenger Corporation; Richard P. Howell, DeLeuw Cather & Co.; Robert L. Kuehne, Michigan Department of Transportation; Clifford A. Woodbury III, LTK Engineering Services; Larry D. Kelterborn, LDK Engineering Inc.; and Charles J. Engelhardt, Silver Spring, Maryland. In addition, two luncheon speakers, Robert Neely, Texas High-Speed Rail Authority, and Mark Lindsey, Federal Railroad Administration, provided relevant insights to the participants. The steering committee thanks all of these individuals for their contributions to the workshop's success.

CONTENTS

I. SAFETY ISSUES RELATED TO MAGLEV GUIDEWAY AND VEHICLES

A. GUIDEWAY

1. Guideway Design and Construction Standards

PROBLEM 1: Placement of Maglev Structures Within Roadway/Railway Rights-of-Way

The structural integrity of maglev guideways will require a substantial civil structure. If this system is to be placed within the existing right-of-way of either highway or railroad facilities, then consideration must be given to the safety of the structure. Just as important is the issue of providing surveillance devices on the structure or barrier between roadway/railway and the maglev guideway structures.

Objectives

The purpose is to develop specifications for guideway system design to absorb or resist impact on structures, prevent the intrusion of roadway or railway vehicles into the maglev system or damage to structural alignments.

Current Activities

Washington Metropolitan Area Transit Authority conducted critical research on barriers and a computer model has been developed. Testing of acceptable simulation models has not been accomplished. At the Volpe National Transportation Systems Center, a project is underway to identify impacts on rights-of-way and to assess hazards.

Urgency

When a maglev system is to use current roadway or railway rights-of-way or cross these facilities on elevated structures, then this issue is of immediate urgency.

PROBLEM 2: Switches for Maglev Guideway (Structural, Mechanical, and Operational Aspects)

The theory and practice of cost-effective switching needs to be determined. The range of tolerable variations is not defined.

Objectives

The purpose is to investigate the range of tolerable variations and to determine conditions that constitute a catastrophic variation. (Vehicle safety, switch movement time, interlocking, and route integrity are some areas of concern.)

Urgency

High priority.

PROBLEM 3: Safe Egress from Maglev Systems under Emergency Conditions

Some maglev systems may be elevated. If in an emergency vehicles have to come to a stop, the evacuation of personnel from an elevated guideway may present a problem.

Objectives

The objective of the research is to evaluate the effectiveness and the impacts on guideway/vehicle design of walkways or railings and platforms with ladders or other means such as chutes.

Current Activities

a. German TransRapid study on fire egress.
b. Pasler and Hofman report of March 16, 1990, on Safety Concept for the Maglev Train.

Urgency

High priority.

PROBLEM 4: Failure Monitoring for Maglev Guideways

More needs to be known about methods of quantitative and qualitative (real time) monitoring of maglev "track fatigue" and potential failures. Of special interest is preventing unexpected sudden failures. Some monitoring schemes feature the inclusion of monitors in the guideway for inspection. Others have vehicle-monitored data relayed to the system.

Objectives

The purpose of this work is to determine what *can* be monitored by the vehicle or guideway and what *must* be monitored by the vehicle or guideway.

Current Activities

TransRapid is undergoing tests of a vehicle-bound monitor to relay information on alignment and integrity.

Urgency

High priority.

PROBLEM 5: Effects of Variations in Climate and the Environment on Maglev Guideways

Existing test facilities for high-speed maglev have not experienced all climatic and environmental factors, such as

- Snow, ice, rain, and wind;
- Lightning or severe electrical storms;
- Earthquakes.

Objectives

Determine the expected effects on guideway utility, integrity, and lifespan from the full range of climatic and environmental conditions.

Current Activities

German and Japanese test facilities.

Urgency

High priority.

PROBLEM 6: Effects of Maglev Guideway Superelevation on Vehicle/Guideway Design, Roll Stability, and Safe Egress

Current practice allows superelevation of 24 degrees (12 degrees on guideway and 12 degrees on vehicle), yet applications don't exceed 20 degrees, ostensibly because of considerations of comfort and safety (e.g., derailment). Such considerations loom large in vehicle design and location of guideway, but often can conflict with economic goals.

Objectives

Determine the relationships between superelevation (for more direct guideway routing) and design (interactive) of vehicle and guideway, roll stability of vehicles, and provisions of safe egress under emergency conditions.

Current Activities

FRA has research programs in progress for development of maglev systems in the United States.

Urgency

Low priority.

2. Tunnels

PROBLEM 1: Aerodynamic Issues, Problems, and Research Needs Related to Maglev Vehicles in Tunnel Operations—Human Factors

There is insufficient information available on the tolerance of passengers to pressure and pressure changes, and therefore we cannot determine conditions under which vehicles will need to be sealed or pressurized to ensure passenger safety. There is a need to establish standards for noise (which may be site-specific) both for vehicle transit at side of guideway and for tunnel entry/exit.

Objectives

The objective is to evaluate the safe level of human tolerance to rapid pressure changes to determine design requirements of vehicles for being sealed or pressurized and to establish standards for noise because of vehicle transit at the side of the guideway and because of tunnel entry/exit.

Current Activity

Research will probably show that experience and standards are available from civil aviation and aerospace industries. The National Maglev Initiative includes efforts in noise evaluation. Japanese, German, and French high-speed rail and maglev projects may have included useful research in this field and should be further developed.

Urgency

Medium priority.

PROBLEM 2: Aerodynamic Issues, Problems, and Research Needs Related to Maglev Vehicles in Tunnel Operations—Modeling

In the development of a maglev system in the United States, information is needed to:

a. Identify the tradeoffs between vehicle cross--section, lateral separation, operating speed, and tunnel size.

b. Design tunnels for safe operation (considering venting/side arms/entry and exit canopies).

c. Consider hazards posed by debris on guideway, particularly in tunnels.

Objectives

The purpose of this research activity is to develop a modeling capability validated by test data (obtained in cooperation with operations of high-speed maglev systems in Germany and Japan) to allow aerodynamic drag forces (steady state and transient) to be determined as a function of the above safety parameters.

Current Activity

Argonne National Laboratory is investigating modeling of maglev design and may include aerodynamics associated with tunnels.

Urgency

Medium priority.

B. VEHICLES

1. Crashworthiness of Vehicles

PROBLEM 1: Crashworthiness

As high-speed maglev transportation systems emerge in the United States, the question arises as to whether there are adequate safeguards to protect passengers and train crews in the event of collisions with other objects. Are regulations necessary to ensure survival and minimize injury by requiring design strengths and configurations of vehicles? Should restraint be required for protection of passengers?

Objectives

The objective of this proposed research is to perform an analytical study and testing program sufficient to establish crashworthiness requirements for maglev transportation systems. Included in this study is an investigation into the adoption of high-g seat belt restraint or other methods of protection such as air bags.

Current Activities

As part of the National Maglev Initiative, a broad agency announcement was issued requesting proposals for research in this area.

The FRA is initiating studies of crashworthiness of high-speed rail systems.

FRA is conducting an assessment of safety of maglev transportation systems.

Urgency

High priority.

2. Braking Capabilities of Vehicles

PROBLEM 1: Safety Verification and Performance Standards Relating to Maglev Braking Systems

Currently, the FRA relies on regulations that tend to be technology-specific and adopted from years of conventional railroad operating experience. FRA also relies on industry standards and practices that relate to conventional railroads and are not performance based. It may be extremely difficult to apply the existing braking regulations and performance standards to the emerging maglev technologies. Maglev systems' primary and secondary braking systems differ greatly from conventional steel wheel/rail systems. It is important that performance standards and safe braking verification methods be established to ensure controlled deceleration in conditions of normal operations and in the event of an emergency.

Objectives

The objective of this proposed activity is to conduct a review of the braking systems of maglev systems currently under testing and to develop a generic set of performance criteria that must be attained by any maglev-type system. This would be done for both primary braking as well as for secondary or emergency braking. Requirements for headways, braking, or deceleration rates for primary and secondary systems must be established. The need for redundant braking systems should be considered and appropriate performance requirements recommended.

Current Activities

FRA is currently conducting an assessment of safety of maglev transportation systems. FRA issued a report "Preliminary Safety Review of the TransRapid Maglev System" in December 1990.

Urgency

Of about eight issues raised and discussed by the "Braking Capabilities" workshop, this issue was rated first in urgency for research work.

PROBLEM 2: Braking Rates/Deceleration Limits

Argonne's 0.2-g deceleration limit suggested for HSR and maglev should be reexamined to determine whether or not maximum service and emergency rates should be the same. Were all the potential factors and implications considered?

Objectives

The objective of this program is to determine maximum allowable braking rates for

a. Seated, belted passengers;
b. Standees and unbelted passengers;
c. Tradeoffs between seated, belted passengers versus standees and unbelted passengers;
d. Required stopping distances;
e. Should the operator be able to control the maximum rate up to a set limit?

Current Activities

Passenger restraint scenarios for other modes; NMI BAA or system concept definition projects.

Urgency

Medium priority.

PROBLEM 3: Train Separation

Present activity in the field of maglev in the United States includes both the study and preliminary design of developed maglev systems for several corridors and the consideration of the development of new maglev concepts. The new concepts are to provide the high density of mixed-traffic single vehicles and trains (possibly to include freight) for local and express service.

Objectives

The objective is the development of train separation standards, to establish realistic safe capacities of mixed traffic on a maglev guideway.

Current Activities

Some related R&D is being conducted for conventional railroads under the ATCS project.

Groups are now considering maglev concepts for development with various headways (e.g., 15 sec), braking rates, moving blocks, and lead train assumptions that could lead, if developed, to unsafe operations.

Urgency

High priority.

PROBLEM 4: Alternative Brake Systems for Maglev Vehicles

Maglev systems being tested in Germany and proposed for application in the United States use electrical brake systems both for primary and secondary braking. Primary brakes use the linear motor propulsion system in a negative mode and secondary brakes use eddy current brakes that react with the guidance rail to decelerate the vehicle. Should the electrical supply system fail, the vehicle can be delevitated and dropped on skids to bring it to a stop. At high operating speeds (300 mph) of maglev vehicle, mechanical (skid) braking may be too inconsistent and some other form of fail-safe braking may be required. There is a need to assess alternative braking schemes to determine this capability of braking the vehicle when electric brake modes are totally or partially ineffective.

Objectives

Identify alternative brake systems (hydraulic, aerodynamic, mechanical, etc.) that may have potential applicability for maglev system secondary or emergency brake systems.

Determine methods of improving system reliability and identify methods of improving brake system performance. The result of this research will provide suppliers and regulators with data needed to evaluate the use of alternative brake systems in high-speed maglev systems.

Current Activities

There is very little data published on maglev vehicle brake systems. There have not been any disclosures or proposals to develop a secondary brake system for maglev vehicles.

Urgency

High priority.

Technical and operational issues in the preliminary and final design of high-speed maglev systems will require appropriate standards for brake systems. Failure to resolve brake system issues prior to initiation of system concept design may eliminate promising candidate systems from implementation considerations.

PROBLEM 5: Fault-Tolerant Braking Systems

Current maglev-related activity in the United States centers around the feasibility of maglev as a viable high-speed ground transportation system. Determining its feasibility involves defining the most effective technical approach in providing a safe, reliable, and economic high-speed system capable of operating at speeds up to 300 mph. Critical to this selection is to ensure that the braking capabilities of maglev vehicles provide safe and reliable braking for all modes of vehicle operation.

Objective

The objective of the proposed research activity is the development of information that would enable braking systems to be designed to be fault tolerant. The design of fault-tolerant braking systems would most likely make use of the appropriate mix of redundancy, detection, and diagnostic approaches to enable safe and effective braking for varying degrees of degradation in braking subsystems, equipment, and components. The development of such braking system capability would ultimately enable the FRA to consider the potential acceptance of fault-tolerant braking in FRA's development of maglev braking safety standards.

Current Activities

Maglev development in Germany and Japan has progressed to the point of demonstrating experimental and prototype vehicles. Interest on the part of several operators to build and operate maglev systems in the United States has led to the forming of governmental interagency agreements for evaluating the potential of high-speed maglev systems.

Urgency

High priority.

Many technical, operational, and economic issues in the preliminary and final design of maglev systems will require the application of appropriate safety standards. Timely safety-based standards and regulations are needed to provide to maglev designers the necessary on which information to base their subsystem choices. Should regulations be developed establishing such standards after the designs have been completed, the expenditures to modify their designs would be large.

3. Vehicle Interiors

PROBLEM 1: Maglev Vehicle Occupant Safety

In order to ensure the future usefulness of maglev systems in the United States, it is essential to ensure that the safety level afforded by such systems equals or exceeds that of other high-speed ground transport systems worldwide. In designing maglev systems, it is imperative that occupant safety be granted a high priority. The construction of maglev vehicle interiors will be critical to occupant safety. Therefore, every effort must be made to maximize the safety of maglev vehicle interiors.

Objectives

Consideration should be given to the establishment of regulations pertaining to performance standards for passenger seating, retention of items of mass, and requirements for on-board emergency equipment. Although these regulations need not stipulate emergency condition procedures regarding occupant egress, it would be well to consider regulations aimed at requiring that operators have such procedures in place.

The automotive and airline industries have accumulated a great deal of experience in their efforts to maximize vehicle interior safety, and have been able to implement many key safety designs economically. Parties involved in designing maglev systems should consider gathering the technical and economic information that has been developed as a result of research in other transportation modes.

Current Activities

The following are suggested information sources:

a. Amtrak specifications

b. SAE Aerospace Standard (AS) 8049

c. SAE Aerospace Recommended Practice (ARP) 767

Urgency

High priority.

Maglev system design parameters will require the implementation of appropriate safety standards. Should regulations establishing such standards be promulgated subsequent to design completion, expenditures to correct safety deficiencies could be large.

II. SAFETY ISSUES RELATED TO SYSTEM DESIGN CRITERIA AND OPERATIONS OF MAGLEV AND HIGH-SPEED RAIL PASSENGER SYSTEMS

A. SYSTEM DESIGN CRITERIA

1. Basic Philosophy of System Design

PROBLEM 1: Model System Safety Plans and Evaluation Process

There are many new high-speed rail and maglev technologies being proposed for installation in various states; none have any operating experience in the United States and represent foreign design practice with respect to safety provisions. Early evaluation during the project planning stage or franchise selection process would provide valuable input to the selection authorities. The present practice places the nonfederal authorities at a disadvantage in anticipating the expected federal government position with respect to acceptance under existing or proposed safety requirements.

Objectives

The objective is to develop and publish a model system safety plan including the process by which local and state authorities may conduct system safety assessments of proposed new-technology high-speed rail systems before the award of a franchise to install and operate them.

Current Activities

The FRA Offices of Research and Development and Safety are undertaking safety evaluations of the Trans-Rapid Maglev, X2000, TGV, and ICE high-speed rail systems in connection with proposed applications of these systems in the United States.

Urgency

High Priority

Several projects are in the formulation stage or franchise selection process already. It appears that the approval of the safety aspects of proposed plans will not be available until selection of franchise or construction has already occurred. Federal ruling could adversely affect project progress or cost by introduction of requirements not anticipated by the authorities or developers.

PROBLEM 2: Operator Control of High-Speed Rail and Maglev Systems Under Selective Conditions

There exists a question as to the degree of control that may be entrusted to the vehicle operator/attendant of a high-speed rail or maglev system under various operating scenarios, ranging from fully decentralized operator control to fully automatic centralized dispatcher control over train operation.

Objectives

The object of this research activity is to determine the safety criteria under which each form of vehicle/train control can exist based on human factors, operational requirements, limitations of the technology involved, and environmental considerations.

Current Activities

Various system developers have proffered differing operator control concepts based on initial research and are now in the process of reviewing the existing practice. The advent of new signal and train control systems now in development may alter previous methods of operation and must be followed closely if safety is not to be compromised.

Urgency

Medium Priority.

This area of research will most likely require an ongoing effort to provide all users with an awareness of the new developments in control systems and the training and maintenance implications they may pose.

2. Methodology for Establishing System Design Criteria

PROBLEM 1: Software/Computer Safety

New systems being introduced into rail operations are becoming more complex and rely on computer software and hardware. This reliance on computers also presents problems for all high-speed ground transportation systems as to how one can assess the safety and reliability of the computers used by these systems. How does one know that the system is safe? What constitutes "safe" for these systems?

Objectives

a. Conduct research to develop and evaluate techniques for assessing the safety of computer software and hardware.

b. Establish industry standards for the analysis techniques to determine the acceptable level of risk for these systems.

Current Activities

German, French, and Japanese developments.

Urgency

High priority.

A major problem that must be addressed as soon as possible.

PROBLEM 2: The Safety Design Process

Rail system suppliers are presently asked to provide systems with designs that are redundant to the extent that they may be too complex and create safety problems. Furthermore, a designer or supplier is often asked by the procuring organization to perform a variety of safety analyses for them. There are no standards.

Objectives

There is a need to standardize in the rail industry the process by which the safety system is evaluated. This should be accomplished by providing a standard for the *system* safety design process.

Current Activities

Military efforts have produced a standard that could be modified for adaptation, MIL-STD-882B, System Safety Program Requirement.

Urgency

Urgent. Needs to be done to ensure an appropriate level of safety.

PROBLEM 3: Review of Existing Standards, Regulations, and Guidelines

In many design efforts there are a variety of industry standards that could be applied to the system design. The existing FRA standards do not directly address maglev or high-speed rail. Many of the existing industry standards, U.S. and foreign, could be used in promulgating new safety standards.

Objectives

To review all the existing U.S. and foreign standards related to system safety (track, wheels, current collection, etc.), and to identify if/when they may be applied to maglev or high-speed rail. This includes codes such as the National Electrical Code, ASME, etc.

Current Activities

A small review project is presently being conducted at the Volpe National Transportation Systems Center.

Urgency

Needs to be done before design begins for U.S. applications.

3. Accounting for Track/Train Dynamics in System Design Criteria

PROBLEM 1: Track-Train Dynamics

a. Determine what criteria to use to set track/guideway geometric condition standards that will ensure "safe" operation.

b. Take a fundamental look at track-train dynamics and not just accept and extrapolate current standards for rail geometry.

c. Examine forces on rails and behavior of guideway under dynamic loading (vehicle passage) and transient conditions (e.g., cross winds and tunnel entry/exit).

d. Assess capabilities of existing models for understanding high-speed track/train dynamics.

e. Procure and enhance or develop a comprehensive modeling capability to allow vehicle and guideway motion to be predicted under normal and transient conditions. Emergency and failure modes must be considered (e.g., loss of magnet, locking of secondary suspension, application of various loading forces, etc.).

f. Modeling capabilities must be proven by test data, which could be obtained at Pueblo or by collaboration with HSR and maglev operators/developers in France, Germany, and Japan.

g. Examine implications of current railroad safety standards in the United States, Europe, and Japan in terms of rail and track forces.

h. Evaluate maintenance needs and standards and how to detect deteriorating or unsafe track.

Urgency

Medium-long term.

PROBLEM 2: Track Geometry Variation Limits to Ensure Safety of Track-Train Dynamic Interaction

There is no clear definition of the relations between measured track geometry variables such as profile, alignment, crosslevel, superelevation, and train safety for high-speed operation.

Objectives

Development of measurement parameters and computational algorithms for assessing track and train safety for high-speed operation. Development of inspection strategies to ensure adequate maintenance of track and vehicles for safe operation.

Current Activities

Ongoing FRA research has concentrated on developing safety performance-based standards for track and freight operations at speeds below 50 mph.

Foreign researchers have conducted some studies on inspection strategies using wheel-to-guideway force measurements and comfort criteria.

Limited Amtrak research on use of ride comfort criteria to detect problem track locations.

Urgency

a. Immediate need for defining upgrade requirements for the Northeast Corridor.

b. Immediate need to develop approaches for inspection/maintenance prior to new systems operating.

c. Immediate need to establish superelevation limits to permit new system design.

PROBLEM 3: Review of Vehicle/Guideway Interaction Models and Validation Test Results

In order to set standards and guidelines for vehicle and guideway construction, maintenance, and operating practices in the United States for safe high-speed rail systems, validated models for vehicle/guideway dynamic interaction are required.

Objectives

a. To review the capabilities, limitations, and proven validation of vehicle/guideway interaction models used by developers/operators of current high-speed rail systems with respect to system safety.

b. To recommend action required to provide the necessary analytical tools to analyze the safety of high-speed rail operations and maintenance in the United States.

Current Activities

a. NUCARS model development.
b. SIMCAR model development.
c. MEDYNA model development in Germany.

Urgency

High.

PROBLEM 4: Definitions and Guidelines for Operations Under Adverse Environmental Conditions

Environmental conditions that high-speed rail systems must be designed to cope with must be defined and guidelines for controlling risks due to environmental factors must be developed. Extreme sidewinds, snow accumulation, ice accumulation, flooding, and earthquakes are likely to inhibit the safe operation of HSR and maglev systems. Some basis must be defined for designers and developers of systems to address these conditions.

Objectives

a. To establish a guideline for the use of historical meteorological data to define "worst case" operating conditions for HSR/maglev safety (e.g., 100-year storm conditions.)

b. To provide guidelines for the application of environmental monitoring processes which advise the system operators of potentially unsafe conditions.

Current Activities

JNR uses windspeed monitors on some Shinkansen locations.

Urgency

Medium priority.

4. Ride Quality

PROBLEM 1: Ride Quality Criteria for Maglev and High-Speed Rail Systems

Ride quality criteria have been developed by numerous transportation agencies for their own purposes. International standards exist, but are based on simple motion stimuli such as vertical acceleration and transverse acceleration. These criteria may not be well correlated with safety criteria or with experimental results of passenger judgments of comfort. Research by U.S. DOT and NASA indicates that passenger comfort is determined by many factors besides motion; including noise, temperature, pressure fluctuations, seat characteristics, and visual cues. Effects of additional motion variables, such as jerk, and extreme banking angles (such as may be encountered in maglev) need to be addressed. Further research using realistic simulations with test subjects is needed to define the limits of acceptability in ride comfort of these new modes. Pertaining especially to maglev, these results may place limits on guideway geometry and speed of a new system.

Objectives

a. Prepare a state-of-the-technology report on ride quality criteria applicable to maglev and HSR and the relationship with system safety.

b. Identify what data are lacking and need to be obtained through further research.

c. Conduct research on passenger judgments of ride quality by simulation of environmental variables expected to be encountered especially in maglev, but also HSR.

d. Develop design guidelines relating guideway geometry, vehicle characteristics, rider comfort, and operational safety.

Current Activities

a. AMTRAK has ongoing work relating maintenance of way and ride quality.

b. NASA-Langley has had a research program on ride quality with the development of a computerized estimation model.

c. Other countries, especially Japan, may have research programs underway.

d. U.S. DOT (TSC) had a program of research during the mid-1970s, but it is now inactive.

Urgency

Ride quality is *not* urgent for *safety* purposes, *except* for limitations on safe walking in the aisle or on pressure changes related to eardrum punctures. However, before a new system can be designed, passenger comfort must be taken into account. Acceptability of ride on a maglev system pushed to the limits is unknown. Consequently, research on ride quality for maglev *is* a high priority before the system is designed.

B. OPERATIONS

1. Operational Training

PROBLEM 1: Human Factors Related to High-Speed and Maglev Systems Operation

Consider an analysis of those physical and psychological elements that might impact an operator's ability to function safely. These elements should include such items as performance fatigue; work-rest cycles; impact of being a sole operator; emergency responses; and issues related to the use of a computer system as a diagnostic tool.

Objective

The goals are to ensure that in the selection and training processes, the employees' knowledge, skills, and abilities are compatible with the safety-related goals and objectives of the high-speed rail or maglev systems.

Current Activities

The U.S. Department of Energy is working on elements related to electromagnetic impact that deal with physiological effects as well as reaction time and attention span.

Urgency

In direct proportion to the necessity of selecting personnel and formulating training programs.

PROBLEM 2: Performance Standards

Develop performance standards for the safe operation of high-speed or maglev systems.

Objectives

To begin an analysis of the knowledge, skills, and abilities for ultimate use in developing procedures and training programs.

Current Activities

Original Research.

Urgency

Must be accomplished for national standards as a minimum.

2. Inspection and Maintenance

PROBLEM 1: Inspection/Maintenance Cycles for Maglev and High-Speed Rail Passenger Service

For maglev and high-speed rail, inspection and maintenance cycles are critical when relating to safety because at high speeds (over 125 mph) derailments and collisions result in greater loss of life and injury to passengers and employees and damage to equipment and property than accidents at lower speeds.

Objectives

To determine cycles for proper inspection and maintenance of rolling stock, control systems, and facilities such as guideway, track, and stations. Also must distinguish between cycles (when to perform) for inspection and maintenance for safety and what additional needs there are for comfort or high-quality service.

Current Activities

Study current inspection and maintenance cycles of SNCF (France-TGV), DBB (Germany-ICE), and Japan (Shinkansen) and other railways where high-speed or maglev systems are in service.

Urgency

Need to make preliminary estimate of inspection and maintenance safety requirements and costs before placing such systems in service in the United States.

PROBLEM 2: Adaptability of Foreign High-Speed Rail Inspection and Maintenance Standards

Present U.S. safety codes concerning the inspection and maintenance of all types of railroad equipment (e.g., locomotives, brakes, signals) evolved from earlier technologies. It is believed that they may not be appropriate for modern foreign high-speed trains, and in many cases that these codified standards are not applicable to maglev.

Objectives

The objective is to examine foreign standards appropriate to high-speed guided ground transportation technology and

a. Evaluate their transfer to the United States.
b. Determine if they can be adopted for use in the United States, and
c. Determine if performance, rather than design, standards may be applied to inspection and maintenance safety requirements.

Current Activities

There have been, and will continue to be, feasibility studies and preliminary design projects in the United States for application of high-speed rail and maglev technologies. Also, TRB Committee A2M05 has an ongoing effort to categorize and assess high-speed rail and maglev safety issues. In addition, the FRA has conducted several safety studies of foreign technology applicable to this work.

Urgency

This is an item of high urgency. Several systems from abroad are currently being considered for application in various states.

PROBLEM 3: High-Speed Requirements for New Diagnostic Concepts, Methodology, and Verification Procedures

Maintenance standards for high-speed vehicles and guideways require frequent inspections to ensure the safety and the integrity of the system. Visual inspections may not be adequate to detect defects in many components before they become a safety hazard. Periodic inspection by fixed test facilities or automated guideway geometry test vehicles may similarly fail to locate defects.

Objectives

a. Determine the desirability of on-board monitoring devices to continuously monitor the performance and status of critical components.

b. Determine the feasibility/desirability of using on-board equipment on each vehicle to continuously monitor guideway geometry and/or functioning.

c. Determine the desirability/feasibility of fixed monitoring devices to monitor operation/integrity of active guideway components such as turnouts.

Urgency

Because many of these systems and devices must be engineered into a high-speed rail system, this research problem has a high priority.

PROBLEM 4: Guideway Condition Evaluation

The problem of assessing the integrity of the guideway seems to be more pressing in the case of maglev than for conventional HSR. In the latter case, there are tools and techniques available that are well proven. However, where a maglev guideway includes propulsion/levitation subsystems, as well as the basic structure, which itself is subject to temperature-induced shape changes and material deterioration, accurate convenient methods of determining the status of the entire guideway do not exist.

Objective

Derive a functional performance statement that will focus research on the development of one or more systems capable of assessing the safe compliance of the guideway with structural, dimensional, and geometrical standards.

Current Activities

a. TransRapid—Germany.

b. Japan Railways Research Institute.

c. Argonne National Laboratory.

d. FHWA (bridge inspection and material performance research).

Urgency

High.

4. Emergency Procedures

PROBLEM 1: Emergency Situations Unique to Maglev and High-Speed Rail

At this time, no operating experience has been gained on maglev and high-speed rail in the United States. Although HSR has been operating in Europe and Japan, maglev has not progressed beyond the prototype testing stage. Because of the new technology, the high speeds involved, and limited operational experience, the types of emergencies encountered and the corresponding emergency procedures may be quite different from those known for conventional (domestic) railroads.

Objective

Through investigative research, specify (identify, quantify, and prioritize) the types of emergencies expected to be encountered by HSR and maglev operations in order to allow the development of adequate and comprehensive system emergency plans and procedures applicable to the selected system.

Current Activities

a. Experience of operation of HSR systems in Europe and Japan. (TRB Committee A2M05 subcommittee task.)

b. Consultants, working on HSR and maglev feasibility and conceptual design studies are obtaining operational safety information from system operators and test facility researchers.

c. Emergency experience from domestic operations of conventional railroads, rail transit, airlines, monorail systems, ski lifts, trams, etc., to discern those emergency situations encountered that are applicable to HSR and maglev.

Urgency

The resulting list of scenario emergency situations, applicable to HSR and maglev, will provide a basis for determining which hazards need to be analyzed in the preparation of the system's emergency procedures.

PROBLEM 2: Identify, Quantify, and Prioritize Maglev or HSR Hazards, to Develop Practical and Cost-Effective Emergency Procedures

In order to develop effective emergency response plans and procedures, it is necessary to develop (or apply) methodology suited to maglev and other HSR systems. Otherwise, it will be both costly and less effective to be equally prepared for all conceivable emergencies, without consideration of likelihood, consequence, and cost of preventing or mitigating accidents.

Objective

a. Identify and prioritize accidents/incidents (rank order), both generically for HSR technologies, and specifically (for a chosen technology, site, and operating environment.)

b. Apply proven methodologies that enable definition of acceptable and unacceptable levels of risk, to guide emergency responses (plans, procedures, training).

c. The methodology for identifying, categorizing, and prioritizing emergencies in order to devise cost-effective and practical response and evacuation procedures must be applied to maglev and other HSR concepts proposed for U.S. applications. Based on this, appropriate guidelines or negotiations concerning emergency response planning will be recommended.

Current Activities

ICF Kaiser Engineering has developed, for both USAF and Transit, a methodology that assigns to each hazard a numerical index, based on its probability, severity, and cost of prevention/investigation. This allows ranking of hazards/emergencies and categorization into unacceptable/acceptable ranges, that set emergency response planning priorities.

Urgency

High priority.

PROBLEM 3: Communications in Emergency Situations

In at least two major railroad accidents, (e.g., New York and Chase, Md.) and also in rapid transit, communications interference and inadvertent overtalk have hampered rescue operations. In addition, there often is a lack of communications compatibility between neighboring jurisdictions, which impedes response.

Objectives

a. To examine HSR and maglev routes and means to enhance/standardize communications and minimize problems in normal, abnormal, and emergency situations.

b. To identify potential areas of interference, overtalk, etc.

c. To recommend alternatives that may be acceptable locally and nationally.

Current Activities

In several cities throughout the United States, emergency response forces (fire, police, and medical departments) have or are in the process of converting to 800 MHz.

Urgency

High priority.

III. SAFETY ISSUES RELATED TO SIGNAL, CONTROL, AND POWER SUPPLY SYSTEMS FOR HIGH-SPEED RAIL AND MAGLEV PASSENGER SYSTEMS

A. SIGNAL AND CONTROL SYSTEMS

1. Train Separation, Location, and Route Integrity

PROBLEM 1: Determination of Need For Devices Other Than Cab Signals for Speeds Over 79 mph

Currently in the United States 79+ mph operations require a cab signal system. No additional mechanism is required. What if any should the requirement be?

Objectives

To determine the requirements for information (other than cab signal information) to operate over 79 mph.

Current Activities

There is no active effort to determine the information requirements for high-speed passenger displays on locomotives. However, the railroad industry is looking at information requirements for displays in all freight locomotive cabs.

Urgency

Low priority; as long as a programmable display is available, the response time to determine requirements and to make changes is short.

PROBLEM 2: Validation and Documentation of *Vital* Software

How is the vitality and validity of vital software proven? What documentation is required? How is it proven that software development is done properly?

Objectives

Ensure a logical process that includes standards for validating software, techniques of software quality assurance, and a test protocol.

Current Activities

There are several processes accepted for operating vital systems to assure that the probability of error is acceptable. Systems have redundant voting computers, or multiple independent software programs running in parallel. The nuclear power industry has standards for QA. The Advanced Train Control Systems project has standards of software QA. However, in spite of much effort, there are no set standards for software error rates.

Urgency

There is a high priority for software validation for any vital system. The validation process is likely to be expensive and time consuming.

PROBLEM 3: Determination of Applicability of Existing Regulations to Advanced Train Control Systems

Are new regulations needed or should existing relay regulations be applied to new technology?

Objectives

To modify, materially change, or reevaluate the applicability and utilization of FRA standards to advanced train control systems (ATCS).

Current Activities

The FRA RS & I regulations 49 CFR Part 236 have been reviewed for applicability to ATCS. There is very little in the RS & I that is applicable. The most probable course of action is not to use the RS & I to regulate ATCS.

Urgency

Low priority

PROBLEM 4: Safety of Microprocessors

How are microprocessors determined to be safe? There are no standards currently available. Should standards be developed? Who should develop the standards? How should it be done?

Objectives

To determine safety standards for microprocessors without impeding technological innovation.

Current Activities

There is an abundance of standards for expected failure rates for hardware and standards for failure modes and effects analysis that can be used to evaluate microprocessor-based vital systems. An appropriate reference is ATCS Specification 140 "Recommended Practices for Safety and Systems Assurance," draft version #2, December 1990.

Urgency

High priority, first order of business for any new system.

PROBLEM 5: Feasibility of Unmanned Vehicle Operations

Under what circumstances would unmanned operation be permitted? What is necessary to permit automatic authority generation, without humans in the loop? A comprehensive study of man/machine interface needs to be undertaken to determine automation.

Objectives

Two issues:

a. Unmanned vehicle.
b. Control office automation. Determine automation capability and standards required.

Current Activities

Recommend research into man/machine interface.

Urgency

Low priority; unlikely for intercity passenger trains.

2. Communications

PROBLEM 1: Systems Level Analysis

Usefulness of overall system-level standards (for communications) at federal level or by some central authority.

Objectives

To develop an architecture for communications systems for HSR (steel wheel-rail) and separately for maglev.

Current Activities

The North American Railroads are in the process of developing an advanced train control system (ATCS). Recommend this be used as a guide. As a minimum, be aware of ATCS design and implementation.

Urgency

High priority.

This is the principal issue in communications. Architectural standards for HSR and maglev will allow for safe and efficient use of available spectrum.

PROBLEM 2: Data Integrity

What are the requirements for ensuring digital data communications integrity (i.e., error rate).

Objectives

To develop or prescribe methods to ensure the quality and integrity of communication of data.

Current Activities

Recommend using current ATCS specifications as a guide.

Urgency

This is a subset of Problem 1. Performance standard is best choice.

PROBLEM 3: Communication Coverage

What is the requirement for continuous radio or other data communication coverage (i.e., in coverage, out of coverage) in tunnels and elsewhere.

Objectives

To determine the benefits and value of area of coverage for data communications systems.

Current Activities

ATCS has established requirements for vital train control being out of coverage (i.e., how to handle train out of coverage). Some current systems do not allow operation in case of communications failure or out of coverage.

Urgency

Need to decide the overall architecture first to determine if this issue needs study or not. (Depends on outcome of Problem 1, System Level Analysis.)

PROBLEM 4: RF Band Standard

Availability of RF bands for use by HSR and maglev.

Objectives

To obtain dedicated RF channels for use by high-speed rail transportation systems.

Current Activities

Availability of RF bands is limited. Needs a broad-based study for channel availability.

Urgency

Medium priority.

B. POWER SUPPLY SYSTEMS

1. Electrical Standards

PROBLEM 1: Assessment of Foreign Electrical Safety Standards, Design Codes, and Practices for High-Speed Rail and Maglev Systems

The current activity in the field of high-speed rail (HSR) and maglev in the United States centers around the feasibility and preliminary design studies for several intercity corridors. For HSR, the next step may involve facility design and the selection of a railroad system and equipment for a specific corridor. For maglev, feasibility studies and a demonstration are currently planned. Technical information for the electrical safety standards, design codes, and practices reside principally with HSR and maglev suppliers in Europe and Japan. There is a need to assess the applicability of these safety standards and practices to U.S. operations. Both HSR and maglev systems will be electrified, therefore, there is also a need to ensure safe compatibility with the electric power supply and telecommunications industries.

Objectives

The objective of this proposed research is to develop information from foreign technologies that can be useful to regulatory agencies for the development of standards and regulations to govern the safety and compatibility of HSR and maglev systems designed for operation in the U.S. environment.

Current Activities

The FRA has established a maglev-HSR task force that has been collecting data on candidate foreign technologies. The need exists to assess this data and to determine its applicability in the United States.

Urgency

High priority.

Many technical and operational issues in the preliminary and final design of maglev and HSR systems will require the application of appropriate safety standards. To the extent possible, the standards, codes, and practices to which these systems have been designed for operation in Europe and Japan should be adapted to the U.S. conditions. Should regulations establishing U.S. standards be developed after designs have been completed, the expenditures needed to comply with these regulations would be large.

2. Magnetic and Electric Field Effects

PROBLEM 1: Biological Effects of Electric and Magnetic Fields in the Extremely Low Frequency (ELF) Range (0 to 150 Hz)

Epidemiology as well as laboratory experiments indicate that there are biological effects of ELF fields, which may have health implications. Current concern focuses on abnormal cell growth, reproductive issues, and neurophysiology.

Objective

Most urgent issue at present is the identification of an appropriate set of parameters (electric or magnetic fields, frequency and intensity range, intermittency, relation to earth magnetic fields, biological parameters, etc.). This issue cannot be solved by transportation officials, but it is important to keep fully apprised of state-of-the-science research and to modify and support replication of key experiments with maglev conditions in mind. (Pacemaker effects constitute a separate but important issue.)

Current Activities

Extensive work has been in progress for some time by the U.S. Department of Energy and EPRI as well as programs abroad (notably in Sweden, Italy, and Japan).

Urgency

High priority.

PROBLEM 2: Epidemiology of Railroad Workers

Elevated risks of diseases such as leukemia, brain tumors, and male breast cancer have been identified in a variety of electrical workers. Special studies should be performed on locomotive engineers (as well as airline pilots) and others who perform work in electromagnetic environments.

Objectives

Establish the epidemiology of these occupational groups.

Current Activities

Some 50 occupational studies on the effects of electric and magnetic fields are currently under way.

Urgency

High priority.

PROBLEM 3: Exposure Assessment

A full analysis of the electric and magnetic environment of maglev in time and space needs to be undertaken, including spectral analysis under standard operations and special conditions (start-up, emergency braking, idling, etc.). Comparative studies on other rail and transit systems, such as Washington Metro or Amtrak, should be done as well.

Objectives

To establish a comparative data base defining the actual exposure regime. As a complement, personal exposure dosimetry must be performed to gain an understanding of worker and passenger exposure.

Current Activities

Extensive exposure assessments are carried out by EPRI, Electricité de France, etc., on utility workers.

Urgency

High priority.

PROBLEM 4: Shielding Options

Passenger compartments will have to be shielded from excessive magnetic fields, excessive gradients, and rapid transients which may have adverse health effects.

Objectives

To develop economically realistic options (bucking coils, etc.) and to establish sensitivity analysis for relevant design parameters, avoiding unrealistic and overly detailed solutions. Superconducting films and finite element analysis do not appear to be appropriate at this time.

Current Activities

There is little work in progress in this area, but the basic problem is fairly simple. Detailed designs will only be required when detailed propulsion and levitation mechanisms are being developed.

Urgency

Medium priority.

Should be incorporated in propulsion and levitation design.

IV. SAFETY ISSUES RELATED TO HIGH-SPEED RAIL GUIDEWAY AND VEHICLES

A. GUIDEWAY

1. Design and Construction Standards: Track Centers, Tunnels, and Security Features

PROBLEM 1: Guideway Design and Construction Standards—Tunnels

Although guidelines for rapid transit tunnel speeds may exist in the U.S., adequate speed and safety criteria for high-speed rail tunnels do not exist. Some experience has been gained from foreign high-speed rail systems.

Objectives

To determine the speed and safety criteria for single- and double-track tunnels with various equipment cross-sections and cross-sectional area ratios (to the tunnels) based on aerodynamic effects, including the necessary appurtenances within the tunnel cross section that may affect the piston effect and turbulence that may be created.

Current Activities

No U.S. research on high-speed rail tunnels is known to be available or underway. Foreign experience with high-speed rail tunnels should be reviewed.

Urgency

High priority.

PROBLEM 2: Review Worldwide High-Speed Rail Practices and Summarize the Most Applicable Statements into One Proposal for Consideration

Currently within North America, there are no guidelines for the following areas relevant to high-speed rail system safety:

a. Track centers between HSR mainlines, between mainlines and sidings; between HSR and other rail systems (freight, commuter); between HSR and highways.

b. Tunnels for HSR operation.

c. Security/safety-related conditions: grade crossing, fencing, intrusion detection, overhead structure protection, underpass protection, longitudinal barriers.

Objectives

Use experience abroad to develop guidelines for use in North America relevant to new HSR safety.

Current Activities

FRA task force on safety requirements is reviewing foreign systems.

Urgency

High priority.

PROBLEM 3: Criteria for Security Features

Proposals for new high-speed rail systems in the United States are based on foreign experience and include grade-separated, completely fenced rights-of-way. What criteria should be applied to prioritize these safety and security features to assist in the upgrading or reconstruction of existing corridors? How can owners adequately protect their investment?

Objectives

Develop priority or cost-benefit criteria for safety of security features including at-grade crossing elimination, fencing type and location, intrusion devices, and barrier locations for urban and rural areas, both overhead and under-grade bridge structures, in corridors where HSR operates with other passenger services, other freight services, and within highway rights-of-way. Identify Federal legislative assistance that could expedite or improve the operator's ability to arrest, detain, and charge trespassers as a means of further improving security and safety.

Current Activities

TRB and HSRA are investigating safety criteria, but for new systems.

Urgency

Medium priority.

PROBLEM 4: Determination of Track Centers Appropriate to High-Speed Rail Operations

The pressure-related effects of two trains passing in opposite directions is related to the track center spacing. It is, therefore, necessary that the track centers be so specified that these effects do not produce unsafe conditions and hazardous situations. Track center spacing impacts basic track configurations and tunnel sizing.

Objectives

The objective is to identify the factors that impact the establishment of track center spacing and the magnitude of their contribution to operational safety. Expected to be included here are train speeds, aerodynamic features, size, and mass of vehicle.

Current Activities

The Japanese are conducting experiments related to tunnel pressure effects and means to mitigate them.

Urgency

Medium priority.

2. Track Standards

PROBLEM 1: Development of Track Geometry

Inspection and maintenance standards for U.S. high-speed rail system safety:

a. Current U.S. standards cannot be extrapolated to high speeds. They are not performance based.

b. Specific track standards may need to be vehicle related.

c. Foreign standards may not take advantage of best available technology and may not relate well to U.S. maintenance practices or capabilities.

Objectives

a. Define an approach for developing performance-based U.S. high-speed rail track geometry and ride quality safety standards.

b. Following the above approach, develop performance-based U.S. high-speed rail track geometry maintenance standards.

Current Activities

a. FRA performance-based track standards research is currently focused on low-to-midspeed operations.

b. TRB Circular 351, July 1985, "Safety Factors Related to High-Speed Rail Passenger Systems."

Urgency

Medium priority.

PROBLEM 2: Track Geometry Inspection and Maintenance Practices: High-Speed Rail in the United States

Existing FRA track safety standards are not suitable for application on high-speed rail systems. They are based on limitations due to past manual measurement techniques and are not well related to vehicle response (as demonstrated by current Amtrak experience in the NEC). Current techniques used by other countries may not be applicable in the United States.

Objectives

Compile all current safety-related track geometry and ride quality acceleration standards used by high-speed rail operators in Europe and Japan, including parameters, limits, measurement techniques, and measurement frequencies. Where possible, identify maintenance techniques.

Current Activities

FRA has an ongoing effort to develop performance-based track geometry standards based on safety priority; however, these are focused on the lower-speed regimes. Amtrak has an ongoing evaluation program attempting to correlate car body accelerations with track geometry deviations.

Urgency

High priority.

3. Grade Crossings

PROBLEM 1: Identify Interstate High-Speed Rail Systems

As high-speed rail (HSR) is proposed in different emerging corridors, some existing routes have grade crossings. Defining an interstate rail system that will be improved for HSR service will include identification of those grade crossings that should be examined for safety. Those not adequate must be closed or grade-separated.

Objectives

Identify emerging corridors where HSR is technically feasible and where there exists public need and support. Determine which grade crossings are adequate for HSR service and which are not adequate, and develop mitigating measures.

Current Activities

Several corridors have been examined for HSR service feasibility from economic, cost/benefit approaches. A major consideration in adapting an existing corridor to HSR use will be the treatment, or preferably elimination of, grade crossings. Foreign approaches to grade crossing safety should be examined.

Urgency

Low priority.

Elimination of or protection for grade crossings will have to be developed concurrently with the detailed corridor studies to determine accurate costs for developing HSR in that corridor.

PROBLEM 2: Maximum Allowable Train Speed for HSR Operations Through Grade Crossings

As HSR is developed on existing corridors, grade crossings that provide adequate protection for low speeds will no longer be adequate. Closing the crossings and grade separation are two possible solutions, although both could be prohibitively expensive or generate intense local opposition. Research is needed to determine the threshold speed and what mitigating factors are possible.

Objectives

Determine the safe threshold speed for HSR operations above which grade crossings should either be closed or separated. In those cases where closure or grade separation is not feasible, determine what measures (if any) could be taken to provide adequate protection while maintaining safe high-speed operations.

Current Activities

Demonstration projects for 4-Quad gates and active advance warning signs are proposed for funding by FRA R&D. Review of previous use of traffic signals to supplement these should also be considered.

Urgency

Low priority.

This should be developed before, or in conjunction with, specific HSR corridor studies, and provided for in the design phase. Retrofit of grade crossings after beginning high-speed rail service begins is not feasible.

PROBLEM 3: Innovative Warning Devices

Grade crossing warning devices can be obscured by weather or other conditions and are frequently ignored by highway users. HSR operations will increase the danger and risk to both rail and highway use associated with grade crossings considerably. What can be done to provide adequate protection to those crossings where grade separation or closure is not possible?

Objectives

Determine the most effective mix of grade crossing protection devices (4-Quad gates, active advanced warning signs, traffic signals, etc.) for HSR grade crossings. Stimulate vendors to consider doing research in developing of new devices. Test and compare new devices with existing systems.

Current Activity

Demonstration projects have been proposed for 4-Quad gates and various active advanced warning signs. Foreign train systems have more effective grade crossing protection.

Urgency

High priority.

New devices require considerable lead time for development, testing, and approval. The work must be finished by the time HSR operations begin.

PROBLEM 4: Intelligent Vehicle-Highway System (IVHS)

Grade crossings will continue to present a risk to the highway user, and the risk will increase as HSR is developed. Could a new warning device in the railroad system work with the IVHS to provide adequate, or additional, protection to highway users?

Objectives

Determine the feasibility of having the IVHS incorporate information on the approach of trains at grade crossings. Determine how such a system would be implemented.

Current Activity

FHWA is presently funding research into the IVHS.

Urgency

Low priority.

B. VEHICLES

1. Crashworthiness of Vehicles

PROBLEM 1: Crashworthiness Safety Equivalents

What are the possible trade-offs for crashworthiness design of vehicle structures that maintain an adequate level of passenger safety?

Objectives

Determine the areas such as operating environment, train control, fully automated operation, guideway protection and grade separation, cruise speed, passenger restraints, with safety trade-offs to crashworthiness and attempt to quantify the trade-offs. Possible trade-offs must include considerations of cost.

Current Activities

FRA has studies underway.

Urgency

High priority.

PROBLEM 2: Effect of Operating Environment

What are the distinct operating environments that are possible in the high-speed regime, and what crashworthiness requirements are appropriate for each?

Objectives

The objective is to determine the different and achievable crashworthiness requirements that apply to the different operating speed regimes, i.e., up to 80 mph, mixed traffic; up to 100 mph, mixed traffic; 100 to 125 mph, mixed traffic; and above 125 mph, mode and grade separated, etc.

Current Activities

FRA has studies underway.

Urgency

High priority.

PROBLEM 3: Collision Energy Absorption by Structural Crush

Can high-speed ground transportation vehicles be required to be designed for collision energy absorption by controlled structural crushing? If so, what magnitude of energy absorption is feasible?

Objectives

Begin the process of applying automotive design techniques to rail cars. Find possible alternates to static end strength, at least in part.

Current Activities

French, Japanese, and German designs for new equipment are taking these factors into consideration.

Urgency

High priority.

PROBLEM 4: Derailment of HSR Consists

Is the accordion action typically resulting from the derailment of (or collision, then derailment) a high-speed train predictable? Is it feasible to rely on this for train kinetic energy absorption?

Objectives

Find possible alternate strategies for collision or train kinetic energy absorption.

Current Activities

Review existing derailment models.

Urgency

High priority.

PROBLEM 5: Alternate Methods of Crashworthy Design of HSR Vehicles

Is it feasible to design for crashworthiness of HSR vehicles starting with human survivability criteria?

Objectives

Identify alternative approaches to crashworthy design that do not degrade passenger safety but that might permit new (foreign) technologies to be applied in the United States with relatively minor changes.

Current Activities

All applicable human injury criteria research.

Urgency

High priority.

PROBLEM 6: Crashworthiness Design Overview

What are all the factors that must be considered in reformulating FRA HSR (and maglev) crashworthiness design requirements?

Objective

To cause the most comprehensive review of relevant issues possible, so that at least the most significant are dealt with in promulgating new regulations.

Current Activities

FRA studies are underway.

Urgency

High priority.

2. Braking Capabilities of Vehicles

PROBLEM 1: In-Depth Review of Existing U.S. Regulations and Laws Concerning Braking Systems and Their Applicability to High-Speed Systems

Specific U.S. laws and regulations exist for intercity rail passenger service braking systems. Many questions have been raised as to the applicability of some of these to high-speed systems.

Objectives

Determine why the existing U.S. brake regulations and laws were written, and their applicability to highspeed operations.

Current Activities

Current research in the U.S. is limited below 125 mph and is primarily freight-related.

Urgency

High priority.

PROBLEM 2: Review of Foreign High-Speed System Braking Standards: Existing and Proposed Additions or Modifications

The need exists to develop brake performance standards/regulations to address high-speed train operations with multitype brake systems in the United States.

Objectives

Define the foreign standards (performance specifications) that are, or will be, applied to high-speed systems, currently or planned.

Current Activities

FRA task force is reviewing safety standards of foreign systems.

Urgency

High priority.

PROBLEM 3: Development of HSR Standards and Guidelines

In order to ensure safety in high-speed rail it is necessary for one body (FRA) to issue guidelines that identify acceptable levels of safety and performance for HSR systems.

Objectives

Identify acceptable levels of safety and performance for HSR. The safety and performance criteria will act as the objective to be met through engineering design of brake systems.

Current Activities

These levels of safety and performance already exist (or are already defined by German, French, or Japanese HSR regulating bodies).

Urgency

High priority.

PROBLEM 4: Alternative Braking Systems for High-Speed Rail

Conventional U.S. rail systems primarily use air-operated tread brakes as the principal braking system for stopping a train within the distance allocated by the traffic control system. Electrical dynamic braking is a supplemental system which is not considered in computing stopping distances in the U.S. High-speed rail systems in Europe use electrical dynamic braking as the preferred braking system and integrate the electrical brake with air-operated disc and/or tread brakes to meet the braking profile. At the higher end of the speed regime, the energy dissipated during braking places a strain on the brake system. There is a need to assess alternative braking systems to determine their applicability for meeting or supplementing high-speed rail brake requirements.

Objectives

Identify adhesion-free and other alternative braking systems (hydraulic, eddy current, aerodynamic, etc.) that have potential applicability for high-speed rail system braking. Determine means of ensuring system reliability, and identify methods of improving braking system performance and reliability. The results of this research will provide suppliers and regulators with data needed to evaluate the use of alternative braking systems in high-speed rail systems.

Current Activities

European and American brake suppliers have internal research and development programs; however, FRA is not a participant. Therefore, the research results may be proprietary and are not available for evaluation.

Urgency

Medium priority.

Technical and operational issues in the preliminary and final design of HSR systems will require appropriate standards for braking system safety. Should regulations establishing the standards be developed after designs have been completed, utilization of effective, economical alternative braking systems will not be possible.

3. Vehicle Interiors

PROBLEM 1: High-Speed Rail (HSR) Vehicle Occupant Safety

In order to ensure the future viability of HSR systems in America, it is essential to ensure that the safety level afforded by such systems equals or exceeds that of other high-speed ground transport systems worldwide. It is imperative that occupant safety be granted a high priority. The construction of HSR vehicle interiors will be critical to occupant safety. Therefore, every effort must be made to maximize the safety of the vehicle interiors.

Separate but similar Research Problem Statements have been developed for HSR and maglev systems because the FRA has not established the means of governing development. In addition, the means of egress/access and the operating environment requirements may vary.

Objectives

Consideration should be given to the establishment of regulations pertaining to safety and performance standards (flammability, smoke emissions, toxicity, etc.) for passenger seating, applications and types of materials, retention of items of mass, and requirements for on-board emergency equipment. Although these regulations need not stipulate emergency condition procedures regarding occupant egress, it would be well to consider regulations aimed at requiring that operators have such procedures in place.

The rapid transit, automotive and airline industries, and AMTRAK have accumulated a great deal of experience in their efforts to maximize vehicle interior safety, and have been able to implement many key safety designs economically. Parties involved in designing HSR systems should consider gathering the technical and economic information that has been developed as a result of research in other transportation modes.

Current Activities

The following are suggested information sources:

a. SAE AS (Aerospace Standard) 8049.

b. SAE ARP (Aerospace Recommended Practice) 767.

c. NFPA 130, Standard for Fixed Guideway Systems.

d. ASTM 906, Ohio State University Test.

e. ASTM 119, Floor Structure Fire Barrier.

Urgency

High priority.

APPENDIX A

PARTICIPANT LIST

WORKSHOP ON SAFETY FACTORS RELATED TO HIGH-SPEED AND MAGLEV PASSENGER SYSTEMS

April 7 - 10, 1991
St. Louis, Missouri

Luc Aliadiere
SOFRERAIL

Jay A. Anema
Boeing Commercial Airplanes Group

John Bachman
Louis Berger & Associates

Arne Bang
Federal Railroad Adminis.

Gary E. Bechdol
Florida DOT

Robert T. Berry, P.E.
Burns & McDonnell

Alan Bing
Arthur D. Little, Inc.

Janie P. Blanchard
Bechtel Corporation

Brenda Myers Bohlke
PBQ&D, Inc

Robert Bolduc
SVERDRUP Corp

Chris Boon
CAN. Inst. of Guided Grnd. Trans.

Aviva Brecher
Volpe Nat'l. Trans. System Ctr.

Kristen Burnham
U.S. GAO

Edward Butt
Burlington Northern Railroad

William A. Clifford
Amer. Train Dispatchers Assoc.

Howard Coffey
Argonne National Laboratory

Thomas F. Comparato
Volpe Nat'l Trans. Systems Ctr.

William J. Croisant
U.S. Army Constr. Engrg. Res. Lab

John Cunningham
Nat'l. Railroad Passenger Corp.

Thomas P. Devenny
LTK Engineering Services

William W. Dickhart, III
Consultant to Transrapid Int'l.

Robert Dorer
Volpe Nat'l. Trans. Systems Ctr.

Tony R. Eastham
Queens University

Charles Englehardt
Silver Spring, MD

Allen R. Ferguson, Jr.
Alper & Mann

Sidney I. Firstman, Ph.D.
IIT Research Institute

Donald Gray
Federal Railroad Admin.

Jean-Paul Guilloux
SNCF

Imre Gyuk
U.S. Dept. of Energy

Nazih Haddad
FL High Speed Rail Trans. Comm.

Carl Hanson
Harris Miller Miller & Hanson

William T. Hathaway
Volpe Nat'l. Trans. Systems Ctr.

Richard Howell
DeLeuw Cather & Company

Timothy Howey
Nat'l. Railroad Passenger Corp.

Harvison Hunt
ICF Kaiser Engineers

Thomas J. Huster
TCU Manpower Training Dept.

Donald Itzkoff
Reed Smith Shaw & McClay

Herbert Jansen
TUV Rheinland e.V., ISEB

Richard D. Johnson
Nat'l. Railroad Passenger Corp.

Timothy R. Jorgenson
North Star Mgmt. Associates

Akita Katsuji
Railway Tech. Research Inst.

Larry Kelterborn
LDK Engineering, Inc.

John K. Kesler
ENSCO, Inc.

William Kleppinger
VAPOR MARK IV

Tristan Kneschke
LTK Engineering Services

Ernst Knolle
Knolle Magnetrans

Albert W. Koeske
Westinghouse Air Brake Co.

Robert L. Kuehne
Michigan Dept. of Trans.

Andy Kurtyak
Unit Rail Products

Robert C. Lauby
Knorr Brake Corp.

Hae Lee
Korea Inst. Machinery & Metals

Donald Lindsey
Brotherhood of Locom. Engrs.

Mark F. Lindsey
Federal Railroad Admin.

Marc M. Lucas
SOFRERAIL

Alex Lutkus
CA Public Utilities Commission

Lorne MacMonagle
GE Transportation Systems

Larry W. Malone
Kansas City, MO

Robert W. McKnight
Railway Signaling Historian

William G. Meeker
NTSB

Daniel Metaut
GEC Alsthom

Luitpold Miller
Thyssen Industrie AG Henschel

James L. Milner
The MITRE Corporation

Myles Mitchell
M.B. Mitchell & Associates, Inc.

Howard Moody
Assoc. of American Railroads

Romy Mowbray
HSST Corporation

Robert Neely
TX High Speed Rail Authority

William O'Sullivan
Federal Railroad Admin.

Satoru Ozawa
Japanese Railways

Walt Pearson
SVERDRUP Corp.

John Piasecki
Piasecki Aircraft Corp.

Jerome R. Pier
Allied International Corp.

Richard H. Priddy
CSX Transportation

Michael Proise
Grumman

Charles Quandel
Alfred Benesch & Company

Frank L. Raposa
Failure Analysis Associates

Hoy Richards
Texas Transportation Inst.

Louis F. Sanders
ARINC Research Corp.

Andrew Schiestl
BNRR

Thomas Schultz
Federal Railroad Admin.

James A. Smailes, P.E.
Federal Railroad Admin.

Charles H. Smith
FL High Speed Rail Trans. Comm.

Roy Striekert, Jr.
McDermott, Inc.

George Swede
LA County Transp. Commission

Toru Takaki
Japanese Railways

Yutaka Takeuchi
HSST Corporation

Paul Taylor
DKS Associates

Raymond E. Thompson
Battelle

Bruce M. Torrey
GE - Plastics

Joseph Vranich
High Speed Rail Association

Joseph E. Walsh
Federal Railroad Admin.

Robert B. Watson
LTK Engineering Services

David A. Watts
Assoc. of American Railroads

Herbert Weinstock
Volpe Nat'l. Transp. Systems Ctr.

P. J. Willis
Nat'l. Railroad Passenger Corp.

Raymond A. Wlodyka
Volpe Nat'l. Transp. Systems Ctr.

Clifford A. Woodbury, III
LTK Engineering Services

Jeffrey Young
Ontario Ministry of Transportation