Mitigating the Consequences of Accidents

Human error or mechanical failure will always have the potential to cause accidents, no matter how advanced and comprehensive accident prevention efforts are. In light of this reality, the Volpe Center has played a critical role in identifying methods by which the human consequences of accidents (injuries and fatalities) can be mitigated.

The previous section of this journal discussed approaches to prevent accidents in the transportation sector. However, if an accident occurs, effective strategies must be developed to minimize the effects in terms of loss of life, injury, and property damage. The Volpe Center's work in this area ranges from occupant protection strategies to providing guidance on how to respond to accidents in a way that minimizes their negative effects. The results of these activities contribute to developing safer vehicles in all transportation modes and support DOT's role in establishing appropriate regulations that protect the safety of travelers.

CRASHWORTHINESS AND BIOMECHANICAL RESEARCH

Determining the crashworthiness of vehicles, or what happens to vehicles in case of an accident, is a crucial step in shaping how to mitigate its consequences. The Center supports DOT and its work with industry in developing vehicles that prevent occupant and non-occupant injury in the event of an accident. This entails investigating the crash behavior of structures and materials. Biomechanical research studies are carried out to develop a better understanding of the human tolerance to injuries resulting from crashes. In these areas the Center develops scenarios and methodologies for objective and reproducible testing and evaluating.

BIOMECHANICAL MODELING: A mathematical (finite element) model of THOR, a specialized crash test dummy used to assess trauma in crash test situations.

Motor Vehicle Crashworthiness, Biomechanical Research, and Data Analysis

In support of the National Highway Traffic Safety Administration (NHTSA), the Center applies technologies from a broad range of disciplines to assess the structural integrity and crashworthiness of transportation vehicles and systems and to study the effects of injury-causing forces and kinematics experienced during a motor vehicle crash. The Center is developing injury mitigation strategies to decrease the number of deaths and injuries caused by motor vehicle accidents each year. The Center's research has included: anatomic modeling of the head and thorax to achieve a better understanding of what happens to the human body in crash situations; studying problems caused by vehicle incompatibility where the wide range of vehicle sizes on U.S. roads creates higher risks; and analysis of crash test data, which will contribute to a better understanding of the causes of injury and ultimately result in designing safer vehicles.

BIOMECHANICS RESEARCH

Biomechanics modeling and research is conducted to develop a better understanding of human tolerance to injuries resulting from the range of automobile collisions and restraint systems, and to develop improved biomechanical criteria for evaluating human injury. To reduce deaths and serious injuries to motor vehicle occupants, researchers need to understand how the human body physically responds to the forces and kinematics generated in motor vehicle collisions, and to understand the structural mechanisms that generate these forces that injure vehicle occupants during crashes. The Center has supported NHTSA in the areas of structural and biomechanical research since the mid-1980s, largely through the use of finite element methods to study automobile impact mechanics, develop improved injury criteria, and to develop injury mitigation strategies.

Using finite element modeling, mathematical models of full vehicles, anthropomorphic test devices and detailed anatomic representations of the brain and thorax—critical regions for evaluating human injury—have been constructed for studying impact response, injury mitigation strategies, and effects on human injury. These models are a cost-effective way to conduct research and provide answers to the safety issues facing NHTSA and the automobile industry.

Under NHTSA sponsorship, the Center has developed a finite element model of an advanced crash test dummy named THOR. The THOR model has a physical (i.e., hardware) counterpart, and both the model and physical dummy utilize more comprehensive instrumentation and incorporate advanced bio-fidelic features for improved evaluation of injury in both modeling and crash testing. THOR is designed to facilitate the assessment of whole body injury in a variety of restraint environments and to act as a tool in crash safety research. THOR could become an international standard or, at least, strongly influence an eventual definition of a standard international crash test dummy.

FLEET SYSTEMS MODEL

One of the challenges of crashworthiness research is to evaluate safety across a range of vehicle classes, types of crashes, and types of restraints. To this end, the Center is supporting NHTSA in developing a fleetwide systems model designed to evaluate the vehicle crashworthiness and the potential safety performance of a class of vehicles under many possible scenarios. This model uses the results of other ongoing research—crash testing, mathematical modeling, occupant modeling, and analysis of crash statistics—to evaluate a range of crash conditions.

VEHICLE COMPATIBILITY

The increase in the number of sport utility vehicles (SUVs), vans, and pick-up trucks on U.S. roads has resulted in a wide disparity in vehicle size and in a higher risk of injury or fatality to occupants of smaller vehicles in crashes. This disparity, or vehicle incompatibility, and the concomitant risk is described and measured in terms of vehicle "aggressivity." Simply stated, a larger vehicle is more likely to cause injury to the occupants of a smaller vehicle in a crash. Volpe research is endeavoring to determine the best combination of vehicle characteristics to reduce fatalities and injuries in motor vehicle crashes between dissimilar types of vehicles.

CRASH TESTING VEHICLES

The Volpe Center assists NHTSA in performing research to improve crash tests that will ultimately result in better injury criteria and vehicle designs with an increased probability of occupant survival and less severe injuries. Recent Volpe work in this area has focused on side-impact crash tests. The data from

NHTSA's Crash Injury Research and Engineering Network (CIREN)

CIREN: A "Learning Laboratory for Lifesaving"

The CIREN project, sponsored by NHTSA, demonstrates a multifaceted approach to minimizing the effects of accidents. Data on actual crashes are collected and analyzed and this knowledge is used by engineers and manufacturers to design safer vehicles and by physicians and researchers to help improve the treatment of accident victims.

Since 1996, CIREN centers have been established at ten Level 1 trauma centers throughout the country. (Level 1 trauma centers are nationally certified facilities that serve as comprehensive regional resources and include total care for every aspect of injury, from prevention through rehabilitation.) The CIREN trauma centers are located in major research and teaching hospitals partnered with universities, and are funded by NHTSA, the auto industry, or operate as self-funding entities.

The overall CIREN system is a research tool that is being developed, updated, enhanced, and maintained by the Volpe Center. It provides a common database into which the ten trauma centers can add actual injury case data, which can then be accessed by researchers throughout the United States. The Center has created a standardized data collection process and serves as a data repository and the center of a wide area network (WAN) for all collected data. CIREN's capabilities are based on three key system features: common comparable data elements, rapid nationwide data exchange, and cross-center expertise across the CIREN network.

DESIGNING SAFER VEHICLES

CIREN has provided NHTSA with a substantial number of cases that, on a case-by-case basis, present highly detailed injury data on occupants of vehicles involved in crashes. This detailed injury information includes hospital discharge summaries, radiological images and results narratives, operation notes, autopsy reports, and photographs of injuries. (All personally identifying material is sanitized from the data and images.) The collection and dissemination of this information illustrates the power of CIREN as a data mining tool to capture what really happens in vehicular crashes. This real-world information can be used to reconstruct an entire crash and correlate injuries with the part of the vehicle impacted by the victim. The engineering focus is on crashes, vehicles, safety equipment, occupant kinematics, and injuries, with the aim being improved vehicle design. Volpe and the CIREN system help to translate these lessons into usable information for scientists and engineers nationwide, which will eventually result in safer vehicle designs.

IMPROVING TREATMENT OF ACCIDENT VICTIMS

In addition to providing data for the study of real crashes, CIREN also provides many real-world benefits in improving emergency medical care. CIREN research has been used to help develop new equipment designs and technologies, software, procedures, and training programs:

- Saving lives by faster and more accurate diagnoses, triage, transport, and treatment of the crash injured and by reducing the time it takes to get appropriate medical care to a crash victim by using Automatic Crash Notification (ACN) and other new technologies. ACN systems use wireless telecommunication technologies to immediately alert a private emergency call center when a passenger presses the car's Mayday button or the car's airbag deploys.
- Improving diagnostic tools to recognize occult, or hidden, internal injuries—especially when vehicle occupants are older, female, of short stature, or large girth.
- Educating police, fire, Emergency Medical Services (EMS), physicians, and care providers to recognize crash victims who demand a higher index of suspicion for internal injuries and transport to a trauma center for treatment by using and interpreting data from the crash.
- Designing, developing, and validating URGENCY software for faster and smarter emergency medical care for crash victims. URGENCY software automatically and instantly connects crash-recorded data into crash-severity ratings that calculate the probability of serious injuries in any given crash.
- Improving communications and organization of trauma systems for better care of crash victims.

Under NHTSA's guidance, the Volpe Center continues to enhance CIREN's capabilities with the aim of achieving its mission to reduce deaths, disabilities, and human and economic costs through the prevention, treatment, and rehabilitation of motor vehicle crash injuries.

these tests will be used to validate and complement the analytical and modeling studies addressing the increased presence of SUVs, pick-up trucks, and vans in the U.S. fleet.

STATISTICAL ANALYSIS

Recognizing that real data from actual events are important in augmenting experimental data, NHTSA, with support from the Volpe Center, launched the Crash Injury Research and Engineering Network (CIREN) partnership in 1996. CIREN was developed with the belief that traditional sources of information would be enhanced by improved integration of data collected from actual crashes and multidisciplinary research on serious crash injuries. CIREN represents the continued evolution of collection methods for motor vehicle crash injury information, which has traditionally been gathered using crash test dummies, cadavers, and other means. This data can be invaluable to researchers as they work to design safer vehicles (see sidebar).

Rail Vehicle Crashworthiness and Occupant Protection

> The Center has transferred the experience gained in evaluating injuries to motor vehicle drivers and passengers in crash scenarios to studies being conducted for seat configuration and restraint systems in trains. The same innovative software modeling techniques developed by the Center to measure motor vehicle crashworthiness for NHTSA have been used to provide crashworthiness expertise to the Federal Railroad Administration (FRA).

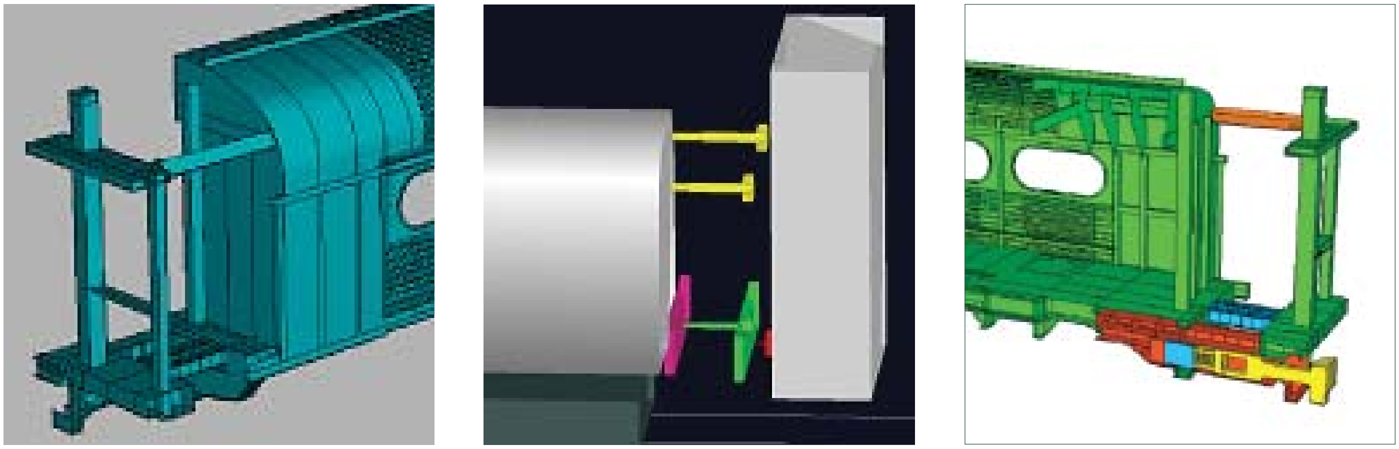
As part of its mission to ensure the safety of the nation's railroads, the FRA promulgates, as well as enforces, regulations for passenger rail equipment and locomotive crashworthiness. To support the FRA in developing these regulations, the Volpe Center conducts research into rail equipment crashworthiness. During an accident, effective crashworthiness preserves the space for the occupants, and maintains the forces and decelerations experienced by the occupants within survivable levels. The approach in conducting rail equipment crashworthiness research has been to propose strategies for improved crashworthiness and to apply analytic tools and testing techniques for evaluating the effectiveness of those strategies. Information from this research has been used to develop the crashworthiness requirements for Amtrak's high-speed trainset (Acela), safety regulations for rail passenger equipment, and proposed crashworthiness regulations for locomotives; these locomotive regulations are expected to be final early next year. Information developed by this research has also been used by the American Public Transit Association (APTA) to develop enhanced industry standards for passenger rail equipment crashworthiness, and by the Association of American Railroads (AAR) to develop enhanced industry standards for locomotive crashworthiness.

Volpe Center engineers apply their expertise in material science, structural engineering, and dynamic modeling to analyze the collision responses of rail equipment. During a collision, there are two aspects of occupant protection to evaluate. The primary collision involves the impact of two bodies (i.e., two oncoming passenger trains, a passenger train and a motor vehicle, etc.) and results in structural damage and possible intrusion into the occupant compartment. Modifications to the structure of passenger cars can decrease the likelihood of bulk crushing and consequently preserve occupant volume. The secondary impact refers to the interaction between the passenger and the interior environment of the passenger compartment. Improvements to the interior occupant environment (i.e., the ability to compartmentalize the occupant, energy absorbing structures, etc.) minimize the likelihood of injury due to secondary impacts. With both modifications to the structure and interior improvements, occupant protection can be significantly improved.

FULL-SCALE RAIL CAR TESTING

Volpe has supported the FRA in conducting research, which involves defining likely collision scenarios, developing computer models to simulate the structural and dynamic results of the collisions, designing and supervising full-scale tests, processing test data, and comparing test measurements with analysis results. Computer models are then used to evaluate a wider range of collision conditions than can be tested.

Initially, a series of full-scale tests were conducted to establish a baseline measure of the crashworthiness performance of conventional passenger rail equipment. Corresponding tests are currently being conducted on a modified design of existing passenger equipment that provides increased occupant protection through the implementation of crush zones in the cab and coach car end structures. Crushable elements are engineered to manage collision energy in unoccupied areas of rail cars and distribute damage to multiple cars in the consist (a number of cars connected together to make up a train), rather



RAIL CRASHWORTHINESS TESTING: These images are from computer models, used both to guide the design of the Crash Energy Management (CEM) crush zones and simulate the full-scale impact tests. LEFT: The finite element model provides information on the force/crush behavior. MIDDLE: A collision dynamics model uses the force/crush behavior in a lumped-mass model to produce estimates of the gross motions of the colliding bodies. RIGHT: A cross-section of a finite element model shows the three primary crushable elements of the CEM coach car design: the pushback coupler, the primary energy absorbers, and the roof absorbers.

than crushing large volumes of the first car, as is characteristic of existing equipment.

Crush Zones Improve Safety. This section highlights research focused on the design, development, and implementation of crushable zones, known as crash energy management (CEM) systems. In single and two-car tests, CEM crush zones were retrofitted onto existing passenger rail cars. These tests demonstrate that the CEM design has superior crashworthiness performance over conventional equipment. Test results show that the CEM equipment performed as engineered and minimized the lateral and vertical motions (that can lead to lateral buckling and/or override).

Computer simulations of the upcoming train-to-train test of CEM equipment indicate that all occupant volume will be preserved and override will be prevented. Structural crush will be shared by crush zones at the ends of each rail car, and all of the crew and passenger space will be preserved. The train-to-train test of CEM equipment, planned for February 2006, is expected to confirm these predictions.

Safer Seats and Tables. The second aspect of addressing occupant protection is analyzing improvements to the secondary collision environment. Conducting accident investigations provides information on causal mechanisms associated with injuries or fatalities. Current efforts are underway to design an improved workstation table as well as forward-facing intercity seats and forward- and rear-facing commuter seats. The improvements aid in compartmentalizing occupants within their seating configuration and limit the secondary loads and decelerations imparted on occupants as they contact their surrounding environment. Five occupant experiments involving these modified designs will be included in the full-scale train-to-train test.

Further information on the results of the rail equipment research can be found in the over 60 papers and reports that have been published. They are available on the Volpe Center's web site. These papers and reports help facilitate the activities of various working groups that apply the results of the research.

FIRE SAFETY REQUIREMENTS

The threat (or hazard) of fire occurring on rail transit vehicles is of major concern considering the large number of passengers carried and the high capital investment involved. Once ignition occurs and a fire spreads, life-threatening situations may develop.

The Volpe Center provides technical support to the FRA and Federal Transit Administration (FTA) in their efforts to reduce potential casualties and damage from passenger train and rail transit vehicle fires. The Center is now directing an ongoing research program using a systems approach to investigate techniques to prevent, detect, contain, and suppress fires. Due to the similarity of passenger rail car and rail transit vehicle furnishings, and to avoid unnecessary duplication of effort, the FTA and FRA fire research program is directed and coordinated by the Volpe Center.

Center staff originally selected the flammability and smoke emission test methods and developed the performance criteria as guidance for selecting materials that FRA and FTA published in 1984. With some modifications, those tests and criteria were made mandatory, as contained in the FRA fire safety regulations issued in 1999 and clarified in 2002. In addition to the material requirements, FRA requires that fire safety analysis be

Collaboration with FRA and Industry

The Volpe Center has demonstrated its role in bringing together stakeholders in industry and government and developing consensus for the greater safety of the traveling public.

Federal Regulations. Results of Volpe rail safety research have been used by FRA to develop Amtrak's high-speed trainset crashworthiness, fire safety, and emergency preparedness requirements, and to develop and improve passenger rail car and locomotive crashworthiness, fire safety, and emergency preparedness regulations. As part of the FRA-established Passenger Equipment Railroad Safety Advisory Committee (RSAC) task efforts, improvements to the passenger equipment regulations are being developed in the areas of structural integrity, emergency lighting, and emergency exit configuration and marking.

Industry Standards and Recommended Practices. Volpe Center staff has worked closely with the FRA and the American Public Transportation Association (APTA), an organization representing the U.S. public transportation industry, as well as the Association of American Railroads (AAR), to develop and improve industry standards and recommended practices.

Center staff has provided extensive technical support to the APTA Passenger Rail Equipment Safety Standards (PRESS) Task Force development of complementary standards and recommended practices to the FRA regulations. APTA has published a manual, which includes standards for passenger rail equipment and locomotive structural integrity, emergency lighting, emergency exit and access signs, and low location exit path marking, as well as a recommended practice for fire safety analysis.

conducted for both new and existing rail cars. Center staff provided extensive technical support to the FRA during the development of the fire safety regulations.

An FRA-sponsored study directed by the Volpe Center concluded that heat release rate (HRR) test methods and fire hazard analysis techniques could provide a means to better predict real-world passenger car fire behavior in a more cost-effective manner than the FRA/FTA-cited fire tests. HRR is defined as the amount of energy a material produces while burning. The fire hazard to passengers of materials can be directly correlated to the HRR of a real-world fire and also permits the evaluation of material interaction and interior geometry effects.

To date, HRR data has been obtained for materials using three types of tests—small-scale, real-scale component assembly, and full-scale car. The HRR data has been used in a computer model to estimate the fire growth using ignition sources and available egress time for different types of car configurations. The conduct of additional fire tests and analysis of commuter rail car and rail transit materials is planned in 2005 and 2006. Results of the fire safety research program will be used to determine appropriate HRR performance criteria for component materials that will provide an equivalent or higher level of safety to the existing FRA/FTA-cited tests.

FIRE PROPAGATION PERFORMED ON AMTRAK INTERCITY PASSENGER CAR SEAT: Materials demonstrate limited flame spread and damage.

PASSENGER TRAIN EMERGENCY EVACUATION TRAINING:
Emergency responders practice removing injured passengers on stretchers through rail car windows.

The use of appropriate small-scale material HRR test data and verified fire computer models for the evaluation of rail vehicle fire safety is consistent with ongoing efforts to develop performance-based fire codes in the United States and Europe.

ACCIDENT RESPONSE— WHEN ACCIDENTS HAPPEN

The "Preventing Accidents" section of this journal describes the engineering and design measures that minimize injuries and fatalities if accidents occur. However, if accidents occur, then the efficiency of the response is an important determinant of the outcome. Safety regulations and engineering are only part of an approach to minimize the consequences of human error, mechanical malfunction, malicious acts, or the forces of nature.

Transportation systems must be ready to handle a variety of emergencies that can compromise public safety. These can include large-scale catastrophic events such as earthquakes and hazardous materials spills, as well as crashes. When such emergencies occur, swift and effective response can often reduce potential loss of life. If countermeasures, such as emergency plans for both response and recovery, are in place and personnel are prepared for emergencies with appropriate training, the effects of the emergencies can be mitigated. The Volpe Center is playing an active role in ensuring that transportation agencies and transportation management professionals are prepared to deal with safety emergencies. Volpe's work includes developing emergency preparedness guidelines, providing appropriate training to transportation professionals, and examining the responses to previous disasters and emergencies to determine the lessons that can be learned from these events.

Emergency Preparedness: Safety First

Even the most carefully designed transportation systems, with state-of-the-art technology staffed by the most highly trained professionals can experience accidents and interruptions in service when confronted with a natural or man-made emergency. The Volpe Center has played an important role in formulating emergency preparedness guidelines and requirements for several modal administrations of the Department of Transportation. Since in the 1980s, the Center has supported the FTA by producing emergency preparedness guidelines for rail transit systems that emphasize the importance of advance emergency planning, as well as training in emergency procedures. The Center has also been a key partner with the FRA in developing passenger train emergency preparedness recommendations in 1993 and establishing emergency preparedness regulations in 1998 and 1999. Examples of the Volpe Center's emergency preparedness work are presented on the next page.

A major Center contribution has been the identification, testing, and analysis of new technology and development of objective and cost-effective minimum performance criteria for emergency lighting levels, as well as conspicuity/visibility criteria for emergency exit and access signs.

Center staff are investigating issues relating to safe and efficient passenger rail car evacuations during various emergency scenarios. Specific areas being explored include: types of emergency exits, their number and configuration as well as their markings and instructions, and emergency lighting. The Center is conducting a study for the FRA to investigate if time-based evacuation criteria, such as that required by the Federal Aviation Administration (FAA) for aircraft, can replace existing prescriptive rules on the number and configuration of passenger rail car emergency exits. Evacuation trials under normal and emergency lighting conditions are planned using commuter rail cars.

Volpe Center Publications on Emergency Preparedness 1980 to 2003 (selected examples)

Publication	Date
The Public Transportation System Security and Emergency Preparedness Planning Guide, FTA *http://transit-safety.volpe.dot.gov/Publications/security/PlanningGuide.pdf*	2003
Passenger Rail Emergency Preparedness Regulations, FRA	1998-99 and ongoing
Critical Incident Management Guidelines, FTA *http://gulliver.trb.org/publications/security/FinalCrisisManagementGuidelines.pdf*	1998
Transit System Security Program Planning Guide, FTA *http://ntl.bts.gov/DOCS/tssp.html*	1994
Recommended Emergency Preparedness Guidelines for Passenger Trains, FRA	1993
Recommended Emergency Preparedness Guidelines for Urban, Rural, and Specialized Transit Systems, FTA *http://transit-safety.volpe.dot.gov/Publications/emergency/Rec_Emer_Prep_For_Urban_Rural_Spec_Tran_Sys.pdf*	1991 (reprinted 1995)
Recommended Emergency Preparedness Guidelines for Elderly and Disabled Rail Transit Passengers, UMTA/FTA *http://transit-safety.volpe.dot.gov /Publications/emergency/Rec_Emer_Prep_For_Elderly_and_Disabled/HTML/UMTA-MA-06-0186-89-1.html*	1989 (reprinted 1997)
Recommended Emergency Preparedness Guidelines for Rail Transit Systems, UMTA *http://ntl.bts.gov/DOCS/609.html*	1985 (reprinted 1992)

LEARNING FROM THE PAST, PREPARING FOR THE FUTURE

The Volpe Center continues its commitment to effective emergency response through its studies of past emergencies, and imparts the lessons learned via reports, information-exchange forums, and training programs for transportation professionals. Examining the response to previous catastrophic events, assessing both successes and failures of these actions to natural, accidental, and malicious disruptive events, can offer valuable guidance. The events of September 11 put the terrorist threat in the forefront, and triggered the need for all public service employees to raise their level of awareness and readiness to deal with conceivable threats to public safety.

As a result of experience in these areas, the Center was well positioned to respond to the request of the U.S. Department of Transportation Intelligent Transportation Systems Joint Program Office (ITS/JPO) and the Federal Highway Administration (FHWA) Office of Transportation Operations to look at emergency preparedness issues related to recent emergencies.

Case studies were developed based on four representative events:

- Earthquake, Northridge, California, July 17, 1994. A 15-second, 6.7-magnitude earthquake near Los Angeles was the costliest disaster in U.S. history, causing 51 deaths, over 9,000 injuries, and major damage to highways, bridges, infrastructure, and buildings.
- Rail Tunnel Fire, Baltimore, Maryland, July 18, 2001. A 60-car train carrying hazardous materials and other freight

When the Lights—and Everything Else—Went Out

In addition to the initial four case studies described in this section, the Volpe Center also performed a study of the effects of the Northeast Blackout, August 14, 2003, on the New York City metropolitan area and the Great Lakes Region.

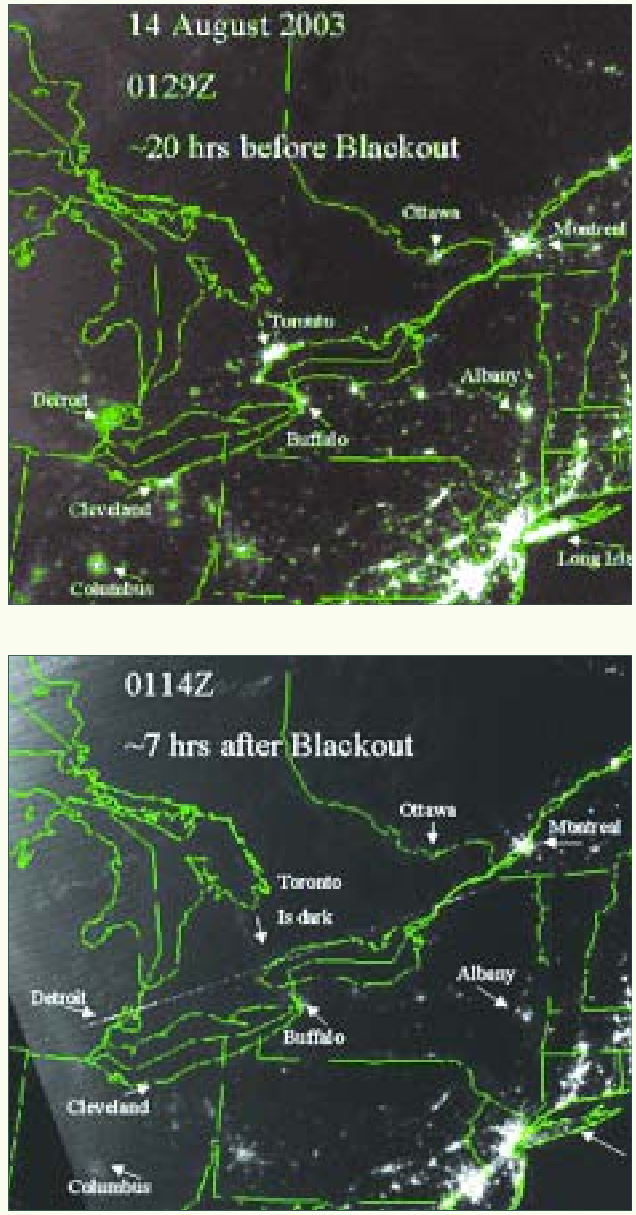
NORTHEAST BLACKOUT, AUGUST 2003

Shortly after 2:00 p.m. on August 14, 2003, a brush fire caused an electrical transmission line south of Columbus, Ohio to initiate a series of failures that caused widespread power outages through the Great Lakes area and east through Pennsylvania, New Jersey, New York, and parts of New England, cutting off power to 50 million people and leaving 3,700 square miles of the United States in darkness. The New York City subway system ground to a halt, stranding more than 400,000 passengers in tunnels. Rush hour traffic was gridlocked in and out of Manhattan, Cleveland, and Detroit as traffic signals went dark. Thousands were stuck in sweltering elevators, some for hours.

The Northeast Blackout—massive as it was—was only one of 56 federally declared disasters in 2003, an average of more than one per week. Each year hurricanes, floods, landslides, wildfires, tornados, avalanches, ice storms, and power outages cause untold damage.

Effects of Catastrophic Events on Transportation System Management and Operations: August 2003, Northeast Blackout New York City, March 2004, DOT-VNTSC-FHWA-04-04. *http://www.itsdocs.fhwa.dot.gov//jpodocs/repts_te//14023.html*

Effects of Catastrophic Events on Transportation System Management and Operations: Crosscutting Study, http://www.itsdocs.fhwa.dot.gov//jpodocs/repts_te//13780.html



NORTHEAST BLACKOUT, AUGUST 2003: TOP: Shows area of blackout before it began. BOTTOM: Shows the same area seven hours after the blackout. (United States Geological Survey)

derailed and caught fire in a more than mile long tunnel under much of the downtown portion of the city.

- Terrorist Attack, New York City, September 11, 2001. The World Trade Center structures burned and collapsed, killing some 2,800 people after being struck by two terrorist-hijacked airliners loaded with fuel and passengers.
- Terrorist Attack, Pentagon, Washington, DC, September 11, 2001. Less than an hour after the first plane struck the World Trade Center a hijacked Boeing 757 crashed into the Pentagon killing 254 people, including all those on the plane and 190 in the building.

The case studies are described in detail in the Volpe Journal (2003) special edition on transportation security. Many of the findings related to emergency response for security situations are also relevant for safety emergencies.

ITS/JPO and FHWA later commissioned Volpe to perform a study on the August 14, 2003 Blackout. The Volpe Center study examined the effects of the blackout on the New York

City metropolitan area and the Great Lakes Region—including Detroit and Cleveland (see box).

Assessing Response to Catastrophic Events—Lessons Learned

As part of this work, Volpe Center staff produced an analysis comparing the events associated with the first four case studies, as well as with the two case studies related to the blackout of August 14, 2003, to examine how transportation agencies responded to unforeseen disasters. The resulting report provides a forum to convey the cumulative knowledge that has been acquired in the course of conducting all six studies. The report presents an overview of each of the areas affected, what occurred on the day of and in the period after the incident, and describes the actions taken by transportation agencies in response to the events.

Each of these events resulted in substantial, immediate, and adverse impacts on the transportation system, and each has had varying degrees of influence on the longer-term operation of transportation facilities and services in their respective region. Each event revealed important information about the response of the transportation system to major stress—and the ability of operating agencies and their public safety and emergency management partners to respond effectively to a crisis. This report

Emergency Response Case Studies—Key Findings

Although each catastrophic event differed greatly from the others, the findings of the various reviews were very similar. Transportation officials and employees in different parts of the country responding to different types of incidents identified comparable actions that must be taken to successfully respond to an adverse emergency situation.

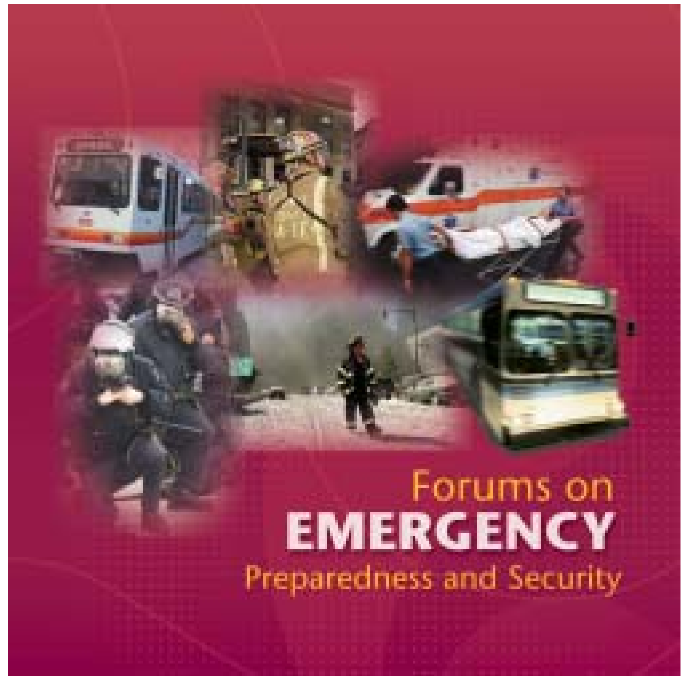
Advanced Preparations and Planning. Emergency planning provides agencies with many advantages during a crisis including predetermined roles, clear and understandable chains of command, availability and readiness of appropriate supplies, and advance identification and rectification of weaknesses in the emergency response. Good advanced planning should also include planning for recovery and restoration. All emergency response planning should be rehearsed, drilled, and reviewed on a frequent basis. Table-top exercises and "field maneuvers" are two of several methods used to evaluate prepared plans.

Institutional Coordination. Cooperation between agencies and organizations is vital to successful emergency response, allowing multiple agencies—sometimes covering multiple jurisdictions—to contribute their strengths and skills during a crisis. Without agency cooperation, emergency response can become fractured, with agency staffs unsure of how to relate to each other or how to jointly participate in a response and recovery operation. This coordination must be established during routine, day-to-day interactions and not during an emergency.

The Role of Advanced Technology. Technology has come to play an increasing crucial supporting role in aiding transportation decision makers during times of crisis. Technology can help agency personnel make better-informed decisions as events unfold and allow them to better coordinate responses with other agencies. It also allows agency personnel to collect and distribute real-time information so that the public can make individual travel decisions. Staffs, however, must understand the limits of technology and acquire multiple technologies to account for those limitations. They must also keep abreast of evolving technologies that may improve their ability to respond more effectively.

Communications. The ability to communicate, internally and externally, is the most critical technological capability required in an emergency. Multiple technical communication methods help ensure proper institutional communication. Moreover, many transportation officials recommended an important action—the development of a non-communications plan—so that staff know where to report in case of a significant communications failure.

Redundancy and Resiliency. The level of appropriate redundancy—for expertise, for equipment, for vehicles, and for technology—will vary from agency to agency, but the need for redundancy cannot be overstated. All agencies must use the process of emergency response planning to identify their needs for redundancy, set priorities for these needs, and then accumulate the necessary equipment and expertise to ensure all vital systems will have some type of backup in an emergency.



LEFT: NEW YORK—VARIABLE MESSAGE SIGN (VMS): On the evening of September 11, 2001. (Photo: Port Authority, New York) RIGHT: EMERGENCY PREPAREDNESS: Forums that bring together emergency responders from different agencies together help to create the community networks that can respond to safety and security emergencies.

emphasizes the transportation aspects of these catastrophic events and lessons learned that could be incorporated into future emergency preparedness and response planning.

The report emphasizes that while each emergency is different there are basic similarities: each event adds to a growing base of knowledge on emergency response and planning, provides new insights into how to prepare, how to plan, how to prioritize, and how to respond. The conclusions presented reflect the growing awareness of the need for careful planning and effective response.

EMERGENCY RESPONSE FORUMS—BUILDING TEAMS

"Connecting Communities"

One way that the Volpe Center has responded to the need for emergency response preparedness is by designing and conducting a series of forums nationwide for the FTA. Transit authorities need to be able to respond to a range of safety issues such as fires or weather-related flooding. The "Connecting Communities: Emergency Preparedness and Security" forums provide local transit, police, fire, medical response, and emergency management professionals with a common vocabulary and meeting place in which to begin working together as teams with a shared purpose. To date, more than 2,000 transit employees and emergency responders have met in these forums.

Transit systems depend on other emergency responders during urgent situations. Bringing together the professional communities is essential to establish mutual understanding, trust, and procedures. In response to this need, Connecting Communities forums have helped create local resource networks to facilitate planning and exercises.

The forums reflect the Volpe Center's organizational development expertise and an understanding of the dynamics and integration required in emergency situations. The forums bring together all the players. Transit people get to know key personnel in their area's emergency response system. They learn about communications resources and who to call in different situations. Emergency responders learn about the various roles in transit, as well as some of the nuts and bolts about how to stop or gain entrance to transit vehicles during an emergency, and how transit staff and equipment can help during a crisis. All the participants discern how much they can learn from each other and gain a better understanding of the importance of continued sharing of resources and ideas.

The Importance of Training

For transportation employees, procedures and equipment have become so dependable that one of the main dangers is the complacency of routine. Probably the most significant factor in determining whether a transportation employee makes a helpful or harmful decision during an emergency is training. Trained and alert transportation professionals can make the difference between success and disaster. Characteristics such as acting responsibly to protect the lives of the public; keeping one's cool and keeping passengers calm; contacting emergency assistance authorities quickly and reporting the essential details accurately; working cooperatively as a member (and sometimes a leader) of a team with a common goal—can all be enhanced through proper training.

In addition, there are role-specific skills and knowledge that transportation employees need to have, ranging from understanding the system's emergency action plans to knowing how to respond to a possible chem-bio attack. Such specialized knowledge can only be imparted through concerted training programs, preferably including simulations and hands-on exercises, and coordinated and supported with other emergency agencies. Moreover, such training needs to be refreshed frequently in order to reinforce and update skills, as well as build a sense of teamwork and trust within the transportation community and across the emergency management community. Volpe's work on emergency guidelines and looking at lessons learned from transportation emergencies is directly relevant to training personnel to respond to emergencies.

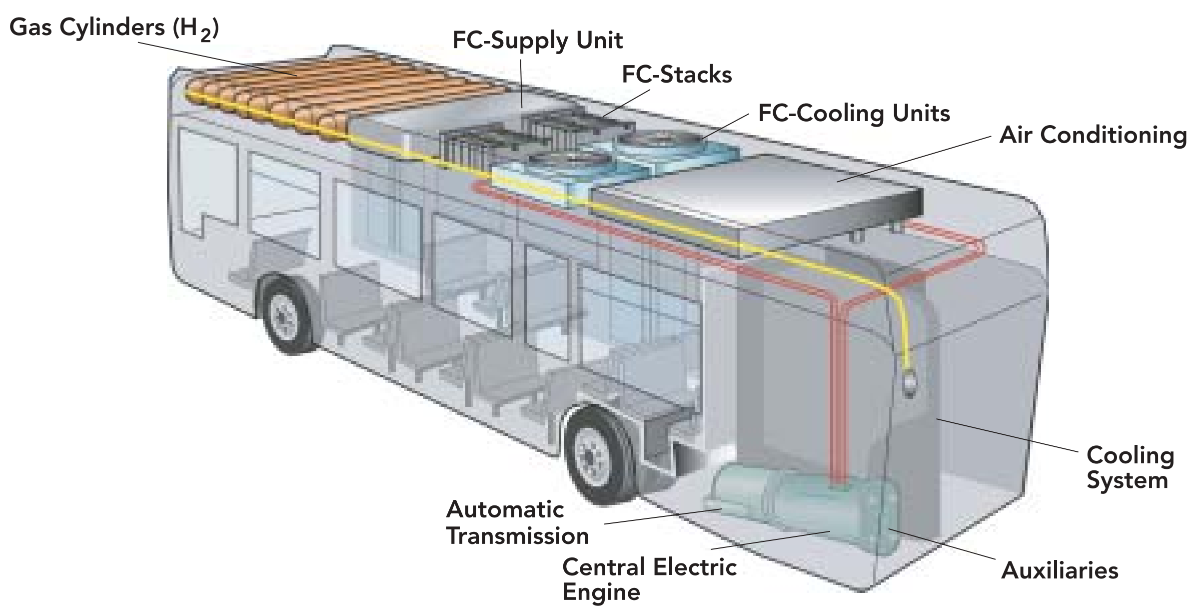
FHWA CASE STUDIES USED IN TRAINING WORKSHOPS

The case studies described in this section have been used in regional workshops sponsored by the FHWA Office of Operations, where transportation officials and emergency response providers came together to discuss emergency preparedness and the role that transportation plays in response and recovery. These workshops were designed to enhance the

HAZMAT AWARENESS POSTERS DEVELOPED BY VOLPE CENTER FOR U.S. POSTAL SERVICE EMPLOYEES AND PUBLIC AWARENESS: "Shipping a Reused Box," "DOT Hazardous Materials Warning Labels," "HAZMAT Ask First!," and "Check before you ship."

Preparing the Way for Alternative Fuels — Volpe Reports Analyze Safety Issues

Publication	Date
Design Guidelines for Bus Transit Systems Using Electric and Hybrid Electric Propulsion as an Alternative Fuel *http://transit-safety.volpe.dot.gov/Publications/cleanair/DesignGuidelines/HTML/DesignGuidelines.htm*	2003
Cylinder Issues Associated with Alternative Fuels	1999
Design Guidelines for Bus Transit Systems Using Hydrogen as an Alternative Fuel *http://transit-safety.volpe.dot.gov/Publications/CleanAir/BTS/BTSDesignGuidelines.htm*	1998
Design Guidelines for Bus Transit Systems Using Liquefied Natural Gas (LNG) as an Alternative Fuel	1997
Design Guidelines for Bus Transit Systems Using Alcohol Fuel (Methanol and Ethanol) as an Alternative Fuel *www.fta.dot.gov/transit_data_info/reports_publications/publications/transit_research_publications/12023_12028_ENG_HTML.htm*	1996
Design Guidelines for Bus Transit Systems Using Compressed Natural Gas as an Alternative Fuel	1996
Design Guidelines for Bus Transit Systems Using Liquefied Petroleum Gas as an Alternative Fuel	1996



HYDROGEN FUEL-CELL BUS

working relationships of personnel from different organizations in the region, and to identify areas for improvement in planning and readiness in the region. They will also help determine next steps and provide input to emergency preparedness guidance being developed at the national level.

> *"The training was worth its weight in gold. I never thought in my lifetime I'd ever see such a problem, or be faced with that kind of problem,"* Dennis Hunsdorfer, Bond County (IL) Senior Center paratransit van operator—when white smoke poured out of a van he was driving, he knew what to do.

TRAINING FOR HANDLING HAZARDOUS MATERIALS (HAZMAT)

Though passenger safety is the central concern for surface and air transportation, it is not only people who are moved by our transportation system. Commodities ranging from raw materials to finished goods constantly criss-cross the nation and international borders. Handling HAZMAT requires extra vigilance as HAZMAT accidents pose a significant potential for public health risks and environmental damage.

Since 1999, the Volpe Center has been involved in developing HAZMAT awareness and instructional materials to train more than 600,000 U.S. Postal Service employees. These materials include an Internet-based training package titled "Sales and Business Service Network" and several videos and posters. These materials identify and describe operating procedures for identifying and properly handling declared or potential HAZMAT packages at various locations including processing and distribution facilities, air mail facilities, and retail operators.

> HAZMAT videos produced for USPS:
> - *First Line of Defense*
> - *Last Line of Defense*
> - *Things Everyone Should Know*
> - *Think Outside of the Box*
> - *Keep the Mail Safe One Parcel at a Time*
> - *HAZMAT Awareness: Everything You Need to Know*
> - *Can You Handle It? Mail Processing Facility HAZMAT Awareness.*

Volpe staff developed and conducted "Train-the-Trainer" courses for 360 USPS air mail handlers throughout the United States, Guam, and Puerto Rico, who in turn have facilitated bi-annual national mail handling forums with aggregate attendance of nearly 10,000 people. The Volpe Center also provides technical support at the forums.

ALTERNATIVE-FUEL VEHICLES—EMERGENCY PREPAREDNESS

In the 1990s, FTA, through its Clean Air Program, began encouraging transit agencies to invest in fleets of buses that use fuels that release fewer and less harmful emissions. The potential use of alternative fuels such as compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (propane), alcohol fuels such as methanol and ethanol, hydrogen, and electric and hybrid electric propulsion in transportation presents challenges, and the purchase of buses that use alternative fuels introduce a new set of safety concerns for the transit operators. Facilities used to store, repair, and fuel these buses must incorporate safety measures that are responsive to properties of and dangers posed by each type of fuel used. Additionally, operations, maintenance, and emergency response personnel must be trained to understand the associated safety concerns and procedures. FTA requested that the Volpe Center research the properties and safety concerns related to the fuels and prepare guidelines for design of the bus facilities and for transit personnel and emergency responders who work with the fuels and buses. The guideline publications prepared by the Volpe Center are listed on page 30.

The Volpe Center completed this series with the publication of *Design Guidelines for Bus Transit Systems Using Electric and Hybrid Electric Propulsion as an Alternative Fuel,* in March 2003. The report provides an overview of electric and hybrid electric bus technologies for transit operators who are contemplating converting from diesel to electric propulsion, and discusses safety issues for operation, maintenance, and storage of buses. Guidelines for designing and redesigning facilities for storing the buses are also suggested. The importance of training for operations, maintenance, and emergency response personnel is emphasized, and suggestions for specific training requirements are presented. The report incorporates comments and lessons learned from transit systems that operate electric buses, consultants, bus manufacturers, and other industry suppliers.