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Preventing Accidents

The most effective strategy for improving safety is to prevent accidents from occurring at all. To this end, the Volpe Center applies a broad range of research techniques and capabilities to determine causes and consequences of accidents and to identify, assess, and safely deploy countermeasures.

The Volpe Center's systems approach can help ensure that safety interventions are innovative, yet practical and sustainable. This section highlights selected examples of Volpe's accident prevention work that improve the safety of motor vehicles, rail, transit, and aviation.

MOTOR VEHICLE SAFETY

On average, in the United States a person is injured in a motor vehicle crash every 10 seconds, and someone is killed every 12 minutes. The human costs to society are incalculable, but total economic costs are more than \$230 billion a year.¹ Over the last several decades, public information campaigns, improved vehicle crashworthiness, and standard safety equipment have all contributed to significant improvements in

motor vehicle safety. For example, between 1975 and 2000, safety belts alone prevented 135,000 fatalities and 3.8 million injuries, saving \$585 billion.² However, these impressive gains could be eroded as driving environments become increasingly hazardous.

- Predicted population growth will result in more vehicles and drivers on already-congested highways.
- Drivers under the age of 24 have the highest rate of involvement in fatal crashes; this age group will increase 19 percent by 2020.
- In-vehicle technologies—from navigation systems to cell phones to enhanced safety systems—will intensify drivers' information load and increase the likelihood of driver distraction, a leading cause of accidents.

To help maintain the hard-won progress in vehicular safety, the Volpe Center is contributing to the development and deployment of safety systems that employ technology

1. *The Economic Impact of Motor Vehicle Crashes 2000*. National Highway Traffic Safety Administration. May 2002. DOT HS 809 446.

2. *Ibid.*

in increasingly sophisticated ways and open new pathways to early intervention.

Tire Safety and ARTEMIS

The August 2000 recall of nearly 15 million Firestone tires was one of the largest automotive recalls in American history. This recall was triggered by a formal defect investigation launched by the National Highway Traffic Safety Administration (NHTSA) in May 2000 after a significant number of complaints were received involving injuries and fatalities related to certain Firestone tires that year. NHTSA linked 174 deaths in the United States to accidents associated with defective Firestone tires on Ford Explorers. Congressional investigations determined that, with more timely product defect information, NHTSA could have intervened earlier. By November 2000, Congress enacted the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act, requiring vehicle and equipment manufacturers to report periodically to NHTSA on a wide variety of information that could indicate the existence of potential safety defects.

NHTSA needed a state-of-the-art database system with capabilities to organize, cross-reference, and analyze the massive flow of industry information required by the TREAD Act. The agency turned to the Volpe Center, which developed ARTEMIS—the Advanced Retrieval, Tire, Equipment, Motor Vehicles, Information System. ARTEMIS was designed to collect and categorize the product data and death and injury data submitted by manufacturers to help NHTSA identify potential defects before vehicle-related injuries and deaths occur. The use of manufacturer-supplied data to identify potential defect trends is part of an “early-warning” system. Volpe supported NHTSA in identifying the requirements and data elements (product components and systems) for inclusion in early-warning reporting categories, and now supports NHTSA in collecting the data. ARTEMIS is used to categorize this data in search of trends that suggest non-random causes of crashes.

ARTEMIS SUCCESS STORY

A recent example of the value of ARTEMIS and its role in effecting immediate safety responses was the much smaller Bridgestone/Firestone tire recall in 2004. With ARTEMIS, NHTSA was able to quickly identify a troubling trend—16-inch tires sold as original equipment on model year 2000 through 2003 Ford Excursions had resulted in five deaths and

20 injuries. The agency notified Bridgestone/Firestone, and the corporation implemented a 300,000-tire recall before the scope of the problem could approach that of the 2000 recall.

Intelligent Vehicle Initiative

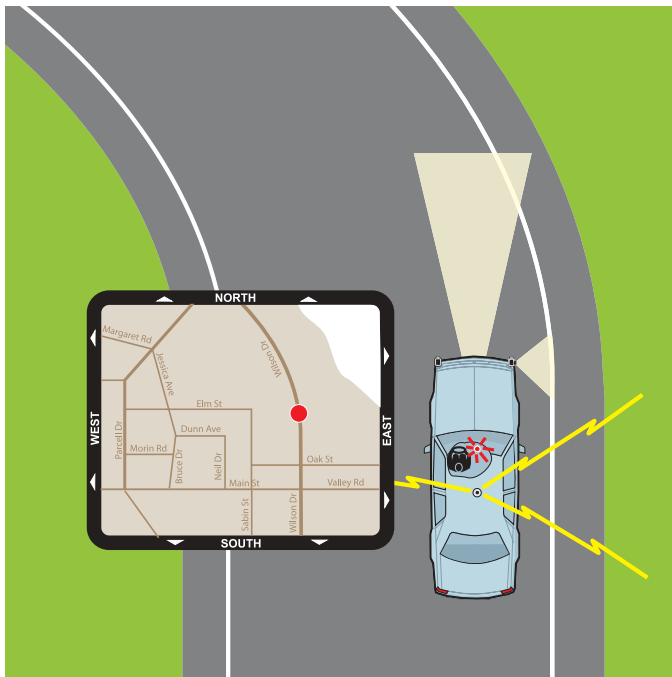
Driver error is cited as a cause in more than 90 percent of police crash reports. Crash-avoidance systems are designed to assess the driving environment and help drivers prevent hazardous driving mistakes. They may keep vehicles in the center of their lane, provide night vision capabilities, or maintain safe vehicle spacing. The Volpe Center assists the Federal Highway Administration (FHWA) and NHTSA in the Intelligent Vehicle Initiative (IVI), which seeks to accelerate the development and commercialization of crash-avoidance products.

UNDERSTANDING HOW CRASHES HAPPEN

Volpe’s IVI work provides a foundation with which industry can design and deploy safe and effective products. Through rigorous analysis of crash scenarios, Volpe researchers have gained a thorough understanding of collision types and causes, and have identified four collision types with the greatest potential for prevention—rear-end, lane-change, crossing-path, and single-vehicle road departures. After developing countermeasure concepts for a crash type, Volpe determines the functional requirements for a potential crash-avoidance system and assesses existing technologies. Industry then designs and builds new systems based on these functional requirements.

ENSURING SAFE AND EFFECTIVE SYSTEMS

As an independent evaluator, Volpe assesses industry prototypes for safety benefits, driver acceptance, system capability, and deployment potential. The Center is currently evaluating three crash-avoidance systems. Two of these systems target a specific type of crash—rear-end or road-departure—and use sensors to detect potential danger; a computer to evaluate the possibility of a collision, and a “driver interface” to relay information to the driver who can then act on it before the collision is inevitable. The third is designed to alert a driver when it detects signs of drowsiness; it uses low-level infrared signals to monitor eye closure. For more on in-vehicle driver-assistance systems, see the sidebar on page 17. Related technical publications produced by the Volpe Center can be found on the Office of Crash Avoidance Research Technical Publications web page at http://www-nrd.nhtsa.dot.gov/departments/nrd-12/pubs_rev.html.



INTELLIGENT VEHICLE INITIATIVE: One of the crash-avoidance systems that the Volpe Center is evaluating warns drivers of impending road-departure crashes.

MOTOR CARRIER SAFETY

While overall highway fatalities have decreased, large truck-related crashes and fatalities in the United States increased through the 1990s. Accordingly, in 2000, the Federal Motor Carrier Safety Administration (FMCSA) was established to reduce the number of crashes, deaths, and injuries involving large trucks and buses. FMCSA set a challenging goal: to reduce the large truck fatality rate by 41 percent between 1996 and 2008. The Volpe Center actively supports FMCSA by:

- Developing, deploying, and maintaining automated safety information resources
- Developing effectiveness measures for FMCSA safety programs
- Developing motor carrier safety fitness assessments through statistical analysis.

Two Volpe-developed systems provide a framework for these efforts: SafeStat (Motor Carrier Safety Status Measurement System) and A&I (Analysis & Information) Online.

Identifying High-Risk Carriers with SafeStat

SafeStat, an automated, data-driven analysis system, determines the current relative safety status of individual motor carriers. FMCSA safety programs employ SafeStat to: identify and

More Accurate Breath Alcohol Measurement

Many factors have contributed to the decrease in alcohol-related fatalities since the 1970s, among them widespread public awareness and stricter drunk driving laws. An important tool for law enforcement is accurate breath alcohol measurement. In support of NHTSA, the Volpe Center conducts studies of techniques for measuring alcohol on the breath. The studies include evaluating instruments for measuring alcohol on the breath of suspected drunk drivers as well as procedures and practices of state law-enforcement agencies. Before any new breath alcohol tester is used by law enforcement, it is tested at the Volpe Center.

Volpe research adds to our understanding of the inherent analytical and physiological variables and potential error rates involved in alcohol testing. Recent studies have addressed the problem of accurately estimating the alcohol level in suspected drunken drivers at the time of their arrest if there was a delay in administering an alcohol test, and the relationship between breath alcohol and breath temperature.

prioritize carriers for on-site compliance reviews, identify and monitor poorly performing carriers for inclusion in the safety improvement process, and support recommendations for roadside inspections. Deployed nationally in 1997, SafeStat has helped FMCSA more efficiently employ its field resources to audit and inspect high-risk carriers. As a result, the large truck crash fatality rate steadily declined between 1997 and 2003.

Making Safety Data Easily Available with A&I Online

SafeStat is also a prominent feature of A&I Online, which disseminates motor carrier safety information via the Internet (<http://ai.fmcsa.dot.gov>). A&I Online was designed to help motor carriers improve their safety performance and to give enforcement officials and others the tools to monitor carrier performance. The evolving audience for A&I Online has grown over the years to include carriers, shippers, truck-leasing companies, and insurance companies—who use A&I to make informed

business decisions—as well as the general public. Effectively, these private sector users have become partners with FMCSA in reducing truck-related crashes, injuries, and fatalities.

Identifying Safe Bus Companies

Recent tragic bus accidents have raised questions about bus companies that the public trusts to supply safe transportation services. Unfortunately, price has often been the sole discriminating factor available to school trip planners, senior citizen groups, community organizations, and businesses for selecting motor coach, school bus, van/mini-bus, and limousine services. In response to growing concerns, an A&I module, the Passenger Carrier Safety web site (<http://ai.fmcsa.dot.gov/Passenger/home.asp>) provides safety information about carriers that operate certain passenger services. Consumers can locate the transportation companies that serve their area and obtain company-specific safety information to help them choose the appropriate carrier and plan safe, reliable trips.

Measuring the Success of FMCSA Safety Programs

Volpe developed two analytic models to measure the effectiveness of three FMCSA motor carrier safety programs—



INCREASING DRIVER ALERTNESS: Driver fatigue can contribute to commercial motor vehicle crashes. The Volpe Center supports FMCSA's enforcement of the new Hours-of-Service rule, which will help ensure that commercial drivers get an appropriate amount of rest. © Walter Hodges/CORBIS

Compliance Review, Roadside Inspection, and Traffic Enforcement. Benefits are estimated in terms of crashes avoided, lives saved, and injuries avoided. Estimated benefits show that as a result of the roadside inspections and traffic enforcements conducted in 2002, 16,387 crashes were avoided, resulting in 781 lives saved and 12,716 injuries avoided. As a result of the compliance reviews conducted in 2002, 1,426 crashes were avoided in 2002 to 2003, translating into 62 lives saved and 1,087 injuries avoided. These models have also been employed to measure the benefits of FMCSA's Hazardous Materials safety programs.

RAIL SAFETY

The resurgence of intercity and commuter passenger rail service brought increased rail traffic. As in other transportation modes, the most evident rail safety issues have been addressed, and innovative approaches that keep pace with industry trends are needed. The Volpe Center supports the Federal Railroad Administration (FRA) as the agency develops proactive safety initiatives in an evolving arena.

Grade Crossings

Highway-rail grade crossings represent a significant portion of the overall risk from railroad operations. Volpe researchers work to develop a more precise understanding of risks to highway and rail users at grade crossings and then determine how best to decrease or eliminate various risk elements.

The Volpe Center's extensive work in this area over more than 30 years has contributed to a significant decline in grade crossing collisions during this period. Despite this progress, railroad passengers and crews, highway users, and even bystanders are still exposed to some level of risk at grade crossings. Many collisions at grade crossings are catastrophic and highly visible.

The Center supports the FRA in all aspects of grade crossing research, from technical to behavioral. Volpe's comprehensive technical support addresses the development of standard evaluation methodologies, the application of visual and audible train warnings, the evaluation of advanced technologies at grade crossings, the development and implementation of new regulations, and demonstrations of Intelligent Transportation Systems (ITS).

It has been shown that a significant portion of grade crossing collisions can be tied directly to human behavior. Volpe's human factors experts can help designers develop systems with the right balance of passive (e.g., signs, markings) and active (e.g., technology) warnings.

MAKING TRAINS MORE VISIBLE

The typical freight car can be hard to see at night. Its exterior—painted in dark colors and frequently dirty—often absorbs the light from motor vehicle headlights rather than reflecting it. Retroreflective materials do enable reflection of the light from headlights back to the motorist. Volpe field operational tests and lab experiments on such materials have considered human factors issues such as the complexity of the visual environment faced by motorists and the relative visibility of various patterns of materials. These activities contributed to the development of a federal rule, effective March 2005, requiring retroreflective materials on locomotives and freight cars.

EVALUATING ACOUSTIC WARNING SYSTEMS

Visual methods for increasing train awareness need to be complemented by audible safeguards. For more than a decade, researchers at Volpe have been investigating how to improve motorist perception of train location through optimal acoustic



TRESPASSER ON A RAIL BRIDGE: This image was captured with a video-based trespass monitoring and detection system that Volpe is developing and testing. The system can also detect trespassers under nighttime conditions.

warning systems. The Center's recent work has built upon earlier train horn research conducted in the 1990s to optimize the sound quality and effectiveness of horns for use on locomotives or in automated wayside horn systems. In addition to meeting the primary goal of improved safety at grade crossings, this sound quality research also focuses on minimizing noise pollution in surrounding communities. A Volpe team has contributed significantly to the development and issuance of the Interim Final Rule and to the Final Rule for Use of Locomotive Horns at Highway-Rail Grade Crossings.

PREVENTING TRESPASSING

Trespassing has always compromised railroad safety, and the temptation for people to cross tracks or a railroad bridge remains strong, posing a major safety threat to rail passengers and employees as well as to the trespassers. Today, there is heightened sensitivity to this problem, due to terrorism and national security concerns. To reduce trespassing on rail rights-of-way, the Center is investigating the use of advanced technologies, such as intrusion-detection systems, at sensitive locations. On a railroad bridge in Pittsford, New York that has experienced a high rate of trespassing, a Volpe team is testing a prototype of a video-based, trespass monitoring and deterrent system.

DEVELOPING STANDARD METHODOLOGIES

To help promote consistency and accelerate the transfer of research results, Volpe is developing standard methodologies for field testing of new technology and for corridor risk analysis.

Assessing Risks of High-Speed Rail. Building on several risk analyses, Volpe staff are developing a methodology to determine the types of warnings and warning devices needed on high-speed rail lines. As part of this effort, Volpe will update a 2003 Report to Congress assessing traffic separation on North Carolina's high-speed rail "Sealed Corridor." A risk assessment methodology based on Volpe's research will be applied to the California High-Speed Rail Corridor project as a prototype for a generic application of the methodology. The methodology will be packaged and delivered as a user-friendly tool to interested states.

Evaluating New Technology. Field testing new components or systems for grade crossing applications requires significant time and resources. A Volpe team is developing a handbook that will provide practitioners with a standard framework, language, and management techniques to efficiently plan

and carry out technology evaluations for readiness and user acceptance.

DEPLOYING INTELLIGENT TRANSPORTATION SYSTEMS

Already widely implemented on the nation's highways, ITS systems that employ digital navigation and communications technologies offer the potential for innovative, multimodal, low-cost warning systems that may be more effective at grade crossings than passive warning devices. The Center assists FRA in evaluating the benefits of deploying Intelligent Railroad Systems with highway ITS. Demonstration systems will integrate multiple technologies, such as variable message signs, train control systems, and in-vehicle devices, to provide advance warning of trains to approaching motorists and pedestrians.

Rail Operations

MINIMIZING THE RISK OF TRAIN DERAILMENTS

Rail industry trends toward more intensive asset use have resulted in added equipment and heavier axle loads, as well as increased rail traffic and higher speeds. These burgeoning demands on the nation's rail system—coupled with the complexities of rail track and equipment—pose emergent challenges to FRA as the agency works with the industry to reduce train derailments caused by track and equipment failure.

Causes of derailments may include adverse interaction between track and vehicle; structural failure of critical components, such as rail fracture; and failure of supporting structures, including track buckling. Volpe contributes to a better understanding of the conditions and mechanisms that lead to these failures and how they can be predicted. Researchers assess the structural integrity, durability, and performance of equipment and track components by applying structures, dynamics, and materials engineering skills in the areas of rail and equipment component integrity, track structural mechanics, and vehicle-track interaction.

In an environment of changing operational, track-construction, and maintenance practices, improvement efforts must make the best use of limited resources. Volpe develops and evaluates inspection tools, and develops and applies predictive models that provide quantitative estimates of safety levels and risks. Volpe research applications include:

- Cost-effective approaches to track inspection and maintenance for industry
- Risk-based performance standards

- Input to FRA's rulemaking and enforcement (e.g., Track Safety Standards and evaluation of waiver requests).

The National Transportation Safety Board has also called on the Center to support derailment investigations. For example, Volpe performed track-buckling analysis for the investigation of the April 2002 Amtrak Auto Train derailment in Crescent City, Florida. At the public hearing on the January 2002 derailment in Minot, North Dakota, a Volpe expert testified regarding the analysis of dynamic impact loads and the fatigue life of joint bars.

Volpe's research into rail and component structural integrity can be found at <http://www.volpe.dot.gov/sdd/pubs-integrity.html>, and track buckling research can be found at <http://www.volpe.dot.gov/sdd/pubs-buckle.html>.

HUMAN FACTORS

In addition to grade crossing issues, Volpe's human factors program also addresses rail operations, in particular the complex environments in which train crews, dispatchers, and maintenance workers perform their jobs. Volpe researchers apply analytical and technical skills, employing methods that take into account the range of human capabilities and limitations. This systematic perspective provides a framework for investigation at various scales, from the role of communication technology in train control, to the safety impacts of sign color and placement, to the safety culture as a whole.

Behavior-Based Safety. A promising model for transportation safety management, behavior-based safety (BBS) is a proactive process that trains employees to identify interactions between the worker, equipment, and systems that create exposure to risk, and to provide positive peer-to-peer feedback and discussion of practices that prevent risk exposure. It is also used to identify and mitigate organizational barriers to safe behavior (e.g., work environment factors, policies, and procedures). A variety of BBS approaches have been used to reduce at-risk behaviors and injury rates in other industries. The Volpe Center is supporting the FRA in assessing BBS for use in railroading. The goal of this work is twofold: to evaluate individual demonstration projects that apply specific BBS methodologies, and to investigate broader issues, such as implementation, cost, and feasibility that could influence industry-wide BBS application.

Analyzing Close Calls. Accidents are often preceded by "close calls," which can provide warnings about unsafe conditions. Studying close calls can help railroads identify safety hazards and develop solutions that prevent accidents. But imple-

The Center for Human Factors Research in Transportation

The Volpe Center's on-site human factors lab, operated under a cooperative research and development agreement with the Massachusetts Institute of Technology, is used for projects across modes of transportation. Lab facilities and equipment include: a railroad dispatcher simulator, a high-fidelity locomotive simulator, three flight simulators, an electronic display development lab, an air traffic control communications laboratory, a sound attenuation room, and a navigation/workload room.

An example of work performed at the lab is research for the FRA that examines the use of train control technology in the locomotive cab. One study addressed what tasks the human should perform, what tasks automation should perform, and what tasks should be shared. Another evaluated the impact of various decision-support aids. To learn more about the Center for Human Factors Research in Transportation, visit <http://www.volpe.dot.gov/opsad/labratory.html>.

menting a reporting system that encourages employees to disclose safety-critical information in a culture of blame requires a sense of trust as well as a voluntary and confidential reporting system. The Volpe Center manages an FRA program designed to demonstrate the effectiveness of a Confidential Close Call Reporting System for the railroad industry.

Improving Switching Operations. Each year, on average, 10 rail employees are killed and 135 are severely injured during switching operations in rail yards. The Switching Operations Fatalities Analysis (SOFA) Working Group (SWG) was formed in 1998 to bring together stakeholders from FRA, the railroad industry, and labor organizations to determine the causes of these events and to make preventative recommendations. The Volpe Center has contributed to SWG since its inception.

SWG issued the *SOFA Report: Findings and Recommendations of the SOFA Working Group* in October 1999, in which five safety recommendations were made to the industry. The recommendations focus on 1) improved communication among crew

members, 2) regular job briefings on the nature of work, 3) discussions of safety issues, 4) minimum distance guidelines for certain types of equipment moves, and 5) mentoring of inexperienced employees. Volpe research was key to identifying contributing factors in specific types of switching fatalities.

In its effort to achieve Zero Switching Fatalities, SWG regularly issues safety information directed at employees engaged in switching operations. In August 2004, the group issued an update to the SOFA Report. (See <http://www.fra.dot.gov/us/content/102> for safety information and SOFA publications.)

TRANSIT SAFETY

Each weekday, about 14 million Americans ride public transportation; 28 million ride on a regular basis. The challenge to the Federal Transit Administration (FTA) is to ensure that transit systems across the country have the information and technology they need to maximize the safety of the riding public, whose numbers increase yearly. The Volpe Center plays a key role in helping FTA meet this challenge, beginning with the development of policy, regulations, and design guidelines. Volpe teams also help foster compliance with federal requirements by providing technical assistance to state and local transit authorities. Volpe's services include compliance monitoring, policy and regulatory analysis, and information sharing.

Advancing Rail Transit Safety

Concern about the potential for catastrophic accidents on rail transit systems led to the State Safety Oversight (SSO) Rule for Rail Fixed Guideways in 1999. For the first time, states were required to oversee the safety and security of rail transit systems, which until that time had been rather autonomous. Volpe supported FTA in developing the initial rules and in revising them based on lessons learned over the first several years of SSO implementation. A major goal is to integrate safety and security more fully into transit projects, from planning through operations.

Volpe teams perform on-site assessments to verify the safety and security readiness of rail transit projects for public use. The Center issues lessons learned, and tracks and disseminates safety-related trends. Audit findings serve as tools for improve-



SYSTEM SAFETY IN TRANSIT: : The Volpe Center supports FTA's efforts to integrate safety and security more fully into the life cycles of transit projects, whether they are new systems or extensions to existing systems. (© Alan Schein Photography/CORBIS)

ment. For instance, since 1999, the number of transit agencies with proactive System Safety Program Plans has grown to 43, and data to improve practices such as accident investigations, corrective actions, and internal audits/three-year reviews have been strengthened.

The Center also undertakes safety-related studies and analyses that encompass the regulatory, administrative, financial, and policy framework within which the SSO Rule applies. These studies also factor in industry practices. Recently published studies include the *Hazard Analysis Guidelines for Transit Projects*, the *Handbook for Transit Safety and Security Certification*, and the *FTA Safety Task Force Report*. These and other documents are available at <http://transit-safety.volpe.dot.gov/Publications>.

Delivering Safety Information

A key element of FTA's Safety and Security Program is educating both the public and the transit industry about safety and security issues, problems, and solutions. The Volpe Center compiles policy, program, and technical information and delivers it through a document clearinghouse and the web site of the Office of Safety and Security (<http://transit-safety.volpe.dot.gov>), both of which the Center maintains. Products include data reports on incidents, injuries, and fatalities; reports addressing

transit issues such as accessibility, alternative fuels, emergency management, fire safety, and substance abuse; government forms; training activities and workshops; and regulations and other rulemaking notices. The web site also contains links to other areas of interest to transit safety and security.

Ensuring Compliance with the FTA Drug and Alcohol Program

More than 3,000 FTA-regulated transit entities across the country are required to have a drug and alcohol program that incorporates testing of safety-sensitive employees. Safety-sensitive employees perform functions related to operating, maintaining, or controlling the movement of any transit revenue vehicle, carrying firearms (by security personnel only), or operating any equipment for which a commercial driver license (CDL) is required. The FTA ensures compliance with this requirement through rigorous on-site auditing, technical assistance, annual reporting, and information sharing. Volpe assisted FTA in the development of the Drug and Alcohol Compliance program and assists in its administration. Volpe developed an Internet-based reporting system with which it collects annual testing results. Through the document clearinghouse, Volpe publishes and distributes these results along with best practices culled from the compliance audits, to the transit community. Volpe teams also organize and administer an annual series of approximately 10 Substance Abuse Management Seminars per year.

Developing Design Guidelines for Alternative-Fuel Vehicles

Although the emissions of alternative fuel vehicles may be less harmful to the environment than petroleum-based fuel emissions, alternative fuels, like traditional fuels, can be hazardous if not handled correctly. Over the last several years Volpe has prepared a series of reports on the safe use of alternative fuels for bus operations. The reports provide overviews of alternative-fuel bus technologies and recommended practices for safe, reliable vehicles and infrastructure. Individual reports focus on compressed natural gas, liquefied petroleum gas, liquefied natural gas, methanol/ethanol, electric power, hybrid electric power, and hydrogen. These and other documents are available at <http://transit-safety.volpe.dot.gov/publications>. These reports also address the need for emergency

response personnel to understand the specific safety issues associated with alternative fuel vehicles. This aspect of the guidelines is discussed in the next section of this journal, which covers how to mitigate the consequences of accidents. The reports are also listed in that section.

AVIATION SAFETY

Aviation safety may be compromised by many factors—such as severe weather, congested airspace, and maintenance or operational errors—that prevent the flight-deck crew from being fully aware of their situation and able to act or react appropriately. The Volpe Center supports the Federal Aviation Administration (FAA) in a variety of initiatives that address these and other factors.

A number of these efforts also enhance the capacity of the National Airspace System. A critical element in aviation safety is the maintenance of adequate separation—the amount of horizontal or vertical distance between planes. Because capacity increases as separations between planes decrease, some of Volpe’s research aims to decrease separation while maintaining or improving safety.

New technologies and techniques enable more effective responses to changing conditions such as weather or equipment outages. Volpe develops sophisticated tools that leverage information and evolving technologies to enable informed decision making along a broad spectrum—from an inspector determining whether to remove an aircraft from service to an air traffic controller giving a pilot clearance for takeoff.

Preventing Runway Incursions

When an aircraft or ground vehicle inadvertently enters (taxi onto/across or lands on) an active runway without authorization, this incursion can present a serious hazard to the aircraft that already occupy the runway. Runway incursions have been blamed in several major accidents; accordingly, both the FAA and the National Transportation Safety Board (NTSB) list the prevention of runway incursions among their highest priorities.

The Volpe Center supports the

FAA’s Runway Incursion Reduction Program, and is engaged in several projects to reduce runway incursions. These projects include surveillance systems that measure and depict airport surface and approaches in real time; automated runway status lights; analysis of incident data to better understand the nature of runway incursions; development of a method for categorizing the severity of runway incursions; and development of educational materials for pilots and controllers.

SURVEILLANCE SYSTEMS

For nearly 30 years, the Volpe Center has supported the FAA’s efforts to provide air traffic controllers with seamless surveillance coverage of airport surfaces and approaches by integrating diverse surveillance systems. Center staff are evaluating and improving the performance of a safety system that converts signals from radar sensors into a map-like display of all vehicles on the airport surface; participating in the development of a next-generation multilateration surface surveillance system; and developing and testing a variety of aviation safety-critical technologies at several airports. Read more about new surveillance technologies in the “SafeFlight 21” sidebar.

TRAINING MATERIALS FOR PILOTS AND CONTROLLERS

A pilot misunderstands a controller’s instruction, an air traffic controller is momentarily distracted, an airport vehicle driver becomes disoriented and drives onto a runway. Under the best conditions, any or all of these incidents could contribute to a runway incursion, but add poor visibility or complex airport layouts and the risks are even higher. Human factors experts at the Volpe Center analyze the complexities of airport surface operations and help those who work in these environments understand the causes of—and help prevent—runway incursions.

For several years, a Volpe team has been analyzing reports of runway incursions, using their results to develop education and training materials for pilots and controllers in succinct and



MEMORY AIDS TOOLBOX: Air traffic controllers often develop memory aids to help them remember specifics, such as which runways are active or when to clear an airplane for takeoff. To help standardize the use of memory aids, the Volpe Center developed the “Memory Aid Toolbox” for the FAA. The Toolbox contains a database of aids used by different controllers around the country. Users can search on several criteria, including a description of the aid, the materials used (e.g., note pad, placard) the region(s) where the aid is used, and the situation in which it is used.

SafeFlight 21

SafeFlight 21 (SF21) is a joint government-and-industry effort to improve the safety, efficiency, and capacity of the National Airspace System using a variety of technologies to provide real-time traffic information to both air traffic controllers and flight crews. The Volpe Center provides extensive technical and management expertise to SF21, which is evaluating and developing new communications, navigation, and surveillance technologies for use on the airport surface, in terminal areas surrounding major airports, in the en route domain (between destinations), and in oceanic operations.

Volpe's accomplishments since the program's inception in 1998 include: deployment of a surface surveillance system in Louisville; deployment of a terminal area surveillance system in Memphis; development of a prototype surface automation system; and development, deployment, and evaluation of two prototype oceanic surveillance systems in the Gulf of Mexico. The Volpe team plays a major role in requirements definition, system engineering, software development, site engineering, and analysis of surface and terminal surveillance systems.

Memphis International Airport. For the FAA, Volpe designed and installed the SF21 Surveillance Server, which fuses surface surveillance radar information with transponder-based multilateration tracks to provide seamless coverage of Memphis' airport operations area; this system was the prototype fusion server for the ASDE-X system being deployed at 32 airports. The Center also evaluated the "outer ring" deployment (see illustration).

Gulf of Mexico. The Gulf of Mexico airspace has two major operating regions and user groups: low-altitude offshore (less than 7,000 ft), utilized by general aviation; and high-altitude oceanic (over 18,000 ft), utilized by air carriers. Both regions suffer significant inefficiencies due to the lack of continuous surveillance during instrument flight rules operations. Provision of surveillance in the offshore region is hindered by its low-altitude nature, which makes coverage by conventional radars economically infeasible. Significant portions of the

oceanic sectors are inaccessible to shore-based sensors, as they are beyond line-of-sight.

Under joint National Aeronautics and Space Administration (NASA) and FAA sponsorship, the Volpe Center developed and evaluated prototypes for two emerging surveillance technologies—Wide Area Multilateration (WAM) and Automatic Dependent Surveillance—Broadcast (ADS-B). These technologies are low cost (in comparison with current radars) and were deployed on offshore platforms. Nine flight test campaigns were conducted using fixed-wing and rotary-wing aircraft.

The WAM system demonstrated the ability to track helicopters down to platform helidecks—an important factor in expediting search and rescue operations. The ADS-B system provides surveillance coverage of approximately the northern 70 percent of the Gulf airspace, and overlaps coverage of Mexican radars on the Yucatan peninsula. This capability can enable aircraft separations to be reduced from approximately 100 nmi to 5 nmi—a dramatic capacity increase that would eliminate multi-hour delays during busy periods. The FAA Joint Resources Council has begun to deploy the WAM system and is considering ADS-B deployment.



MEMPHIS OUTER RING TERMINAL-AREA MULTILATERATION SURVEILLANCE SYSTEM: This system extends surveillance well beyond the surface to 60 nmi from the airport and an altitude in excess of 45,000 ft. Multilateration determines the location of an aircraft by interrogating the aircraft's transponder. The transponder's reply is measured by an array of sensors on the ground that computes aircraft identification and position.

easy-to-read formats. A booklet titled *Runway Safety: It's Everybody's Business*, first published in 2002 and now in its third printing, presents detailed examples of scenarios that led to incursions. Aimed at clarifying the roles and responsibilities of pilots and controllers, it addresses problems from both perspectives and provides tips on how pilots and controllers can improve their performance and help each other work together more effectively. The booklet is available at <http://www.faa.gov/runwaysafety/handbook.cfm>.

Based on this highly successful booklet, Volpe developed a prototype tool for training tower controllers. This interactive CD contains “learn-by-doing” modules that cover topics such as:

- Limits of short-term memory and the effects of distractions
- Effects of expectation and selective attention on information processing
- Common errors in controller-pilot communications
- Teamwork strategies that can help mitigate the effects of individual errors
- Avoiding and managing the effects of fatigue.

RUNWAY STATUS LIGHTS

NTSB's number one recommendation to prevent runway incursions: “Provide a direct warning capability to flight crews.” Volpe is supporting the FAA's Runway Status Lights (RWSL) Program, which will provide a visual indication of runway status directly to the cockpit.

An array of red “stop” lights at each taxiway and runway intersection provides a prompt and unambiguous indicator to pilots that a runway is not safe to enter. The fully automated lights, which are controlled by safety logic software, are integrat-



WAKE VORTEX: Landing aircraft at St. Louis International Airport and some of the Volpe instrumentation suite. Condensation in the air enables vortices from flaps to be visible.

ed with the airport's existing surface surveillance system. RWSL information is also visible on the displays of air traffic controllers. Status lights are intended to reinforce controller commands and act as a safety backup—the pilot and the controller share responsibility for preventing incursions.

The Volpe Center RWSL team is engaged in the development, testing, evaluation, and deployment of runway status lights. The first prototype system, developed at the San Diego airport, is scheduled for operational evaluation in summer of 2006.

RATING INCURSION SEVERITY

Historically, data on runway incursions have been extracted from written observations. To provide an objective and reliable method for determining incursion severity, a Volpe team developed an integrated mathematical model that assigns a quantitative value to incursion severity. The model may be used internationally to achieve a global rating standard.

Understanding Wake Vortex Hazards

As an aircraft generates lift, it creates counter-rotating cylindrical air masses. This pair of wake vortices can pose a hazard to nearby aircraft. Air disasters of the past decade, such as the 1994 crash of Flight 427 in Pittsburgh or the 2001 crash of Flight 587 in New York City, and the hypothesized role played by wake turbulence in these tragedies, serve as stark reminders of the importance of carefully balancing capacity and safety.

Of course, safety is the priority, and FAA regulations clearly define required separations between aircraft. Volpe research is providing a better understanding of the wake vortex phenomenon. The ability to accurately predict the location of an individual plane's wake under particular conditions could lead to modified separation standards that will enable closer spacing and greater capacity while maintaining or even improving current safety margins.

The Volpe Center has supported FAA and NASA Wake Vortex Programs since the 1970s, developing several technologies as well as extensive test programs at several airports to measure vortices generated by arriving and departing aircraft. Volpe developed wake vortex test sites at the JFK and Dallas/Fort Worth international airports in support of NASA's effort to develop an accurate vortex transport and decay model for all atmospheric conditions. For the FAA, Volpe supported a program to make more efficient use of the runways at San Francisco International, a delay-prone airport.

Emerging Issues in Accident Prevention: Fatigue and Distraction

Driver distraction and inattention are contributing factors in 20 to 30 percent of reported vehicular crashes. This statistic highlights the need for research to explore methods by which human factors such as fatigue, distraction, and aging can be better understood and managed. Interventions apply educational and/or technological approaches.

Fatigue

Increasingly, fatigue is being recognized as a critical safety factor. Operator fatigue may produce physical and mental decrements in vigilance, judgment, and decision making that can increase the risk of human error and result in fatalities and injuries. But the incidence of fatigue is underestimated in virtually every transportation mode because it is difficult to measure and quantify. The Fatigue Monitoring and Countermeasures Research Team at Volpe takes a multimodal, systems approach to exploring fatigue and alertness issues.

DOT's Operator Fatigue Management Program. Recognizing that fatigue management requires changes in organizational culture and operator behavior, a multimodal DOT initiative brings together government, labor, and industry to develop tools to aid in understanding and managing fatigue. Volpe staff co-chair the Operator Fatigue Management (OFM) Program, whose recent products include tools such as software to help schedulers design ergonomic work schedules that promote on-duty alertness, fatigue model validation procedures, and the Fatigue Management Reference Guide. For more on the OFM program, see <http://scitech.dot.gov/research/human/ofm.html>.

Drowsy Driver Warning System. Each year, drowsy drivers are reportedly responsible for well over 100,000 automobile crashes. As part of DOT's Intelligent Vehicle Initiative,

the Volpe Center is evaluating a commercially available drowsy driver warning system for NHTSA and FMCSA. The device monitors eye closure and alerts a vehicle operator when it detects drowsiness. The Center will evaluate device performance, safety benefits, driver acceptance, and deployment prospects.

FRA Fatigue Research. Volpe human factors experts have significantly contributed to the FRA's fatigue research, which pursues a non-prescriptive approach to fatigue management that includes the development and implementation of improved fatigue data collection methodologies, better measurement and evaluation tools, and more effective fatigue countermeasure strategies in concert with railroad unions and industry.

Distraction

The continued proliferation of in-vehicle electronic devices—more complex controls, displays, communications devices and entertainment systems—increases the potential for crashes caused by driver distraction. To mitigate this danger, NHTSA is exploring vehicle designs that help ensure that the demands imposed on drivers' attention do not overwhelm their capability to process and respond to information.

SAVE-IT. Important research in driver distraction uses a test vehicle called SAVE-IT (Safety Vehicle Using Adaptive Interface Technology). The Volpe Center provides program management and technical support to this high priority NHTSA project. The goal of SAVE-IT is the development of a central monitoring system that integrates data from in-vehicle technologies and controls the flow of information to the driver through an adaptive driver-vehicle interface. For more on SAVE-IT, see <http://www.volpe.dot.gov/opsad/saveit/index.html>.

Current Volpe efforts are summarized below:

- Collection and analysis of data from Denver International Airport is increasing understanding of the relationship between sound generated by wakes and the potential wake hazard.
- A test at St. Louis International Airport will help determine whether aircraft can be permitted to conduct simultaneous

approaches to closely spaced parallel runways during reduced visibility conditions at that airport and others with similar configurations.

- The Volpe Center maintains an annotated bibliography of abstracts of publications on aircraft wake vortices. The online version is available at <http://www.volpe.dot.gov/wv/wv-bib.html>. 