Truck-Tractor Semitrailer Rollover and Motorcoach Collision With Overturned Truck Interstate Highway 94 Near Osseo, Wisconsin October 16, 2005

ACCIDENT REPORT

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Highway Accident Report

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National Transportation Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2008. ***Truck-Tractor Semitrailer Rollover and Motorcoach Collision With Overturned Truck, Interstate Highway 94, Near Osseo, Wisconsin, October 16, 2005.*** **Highway Accident Report NTSB/HAR-08/02. Washington, DC.**

Abstract: On October 16, 2005, an accident comprising two events occurred on Interstate Highway 94 (I-94) near Osseo, Wisconsin. The first event was the rollover of a truck-tractor semitrailer combination unit. The second event occurred when a motorcoach collided with the wreckage from the first event. About 7:30 p.m. on October 15, 2005, a truck driver departed Munster, Indiana, on a trip to Minneapolis, Minnesota, driving a truck-tractor semitrailer operated by Whole Foods Market, Inc. At 1:58 a.m., the combination unit was traveling westbound on I-94 near milepost 85, when it departed the right-hand travel lane and paved shoulder. The unit left the roadway and entered the earthen, sloped roadside. The driver steered to the left, and the combination unit reentered the pavement and overturned onto its right side, so that it blocked both westbound lanes and shoulders of I-94. About 3 hours before, a group of marching band members from Chippewa High School left the University of Wisconsin to travel back to Chippewa Falls, Wisconsin, in four motorcoaches. The lead vehicle, a 55-passenger motorcoach owned by Chippewa Trails, Inc., was traveling westbound in the right-hand lane of I-94 when it collided with the overturned combination unit about 1:59 a.m. The motorcoach driver and four passengers were fatally injured. Thirty-five passengers received minor-to-serious injuries. The truck driver received minor injuries.

Major safety issues identified in this report include operator fatigue, fatigue technologies and countermeasures, and collision warning systems. As a result of this accident investigation, the Safety Board makes recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration (NHTSA), and Whole Foods Market, Inc. The Safety Board also reiterates two recommendations to NHTSA.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACC	adaptive cruise control
ADT	average daily traffic
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
Chippewa Trails	Chippewa Trails, Inc.
CISR	Center for Intelligent Systems Research
CMV	commercial motor vehicle
CVSA	Commercial Vehicle Safety Alliance
CWS	collision warning system
ECBS	electronically controlled brake system
ECM	electronic control module
EEG	electroencephalograph
EOBR	electronic on-board recorder
ESC	electronic stability control
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMP	fatigue management plan
FMVSS	Federal Motor Vehicle Safety Standard
g	acceleration of gravity
GPS	global positioning system
HOS	hours-of-service
I-94	Interstate Highway 94
ITS	intelligent transportation systems
LDWS	lane departure warning system
LED	light-emitting diode
MRB	Medical Review Board
NHS	National Highway System

NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
PERCLOS	percentage of eyelid closure
RA&C	roll advisor and control
RSC	roll stability control
TEA-21	Transportation Equity Act for the 21st Century
UMTRI	University of Michigan Transportation Research Institute
USDOT	U.S. Department of Transportation
Whole Foods	Whole Foods Market, Inc.
WISDOT	Wisconsin Department of Transportation
WSP	Wisconsin State Patrol

Executive Summary

Between 1:58 a.m. and 1:59 a.m. on Sunday, October 16, 2005, an accident comprising two events occurred on Interstate Highway 94 (I-94) near Osseo, Wisconsin. The first event was the single-vehicle rollover of a truck-tractor semitrailer combination unit. The second event occurred when a motorcoach collided with the wreckage from the first event.

About 7:30 p.m. on October 15, 2005, a 22-year-old truck driver departed Munster, Indiana, on an approximately 436-mile-long trip to Minneapolis, Minnesota, driving a truck-tractor semitrailer operated by Whole Foods Market, Inc. By 1:58 a.m., the truck driver had completed about 323 miles of his trip. The combination unit was traveling westbound on I-94 near milepost 85, at a police-estimated speed of 63 to 69 mph, when the unit departed the right-hand travel lane and paved shoulder at an approximate 3-degree angle. The unit left the roadway and entered the earthen, sloped roadside. The driver steered to the left, and the combination unit reentered the pavement and overturned onto its right side, sliding to a stop so that it blocked both westbound lanes and shoulders of I-94. The truck driver said that following the overturn, he turned off the ignition and was then thrown into the sleeper berth area by another impact.

About 3 hours before this accident, a group of marching band members from Chippewa High School left the University of Wisconsin near Whitewater on an approximately 225-mile-long trip back to Chippewa Falls, Wisconsin. The group was traveling in four motorcoaches and had completed about 195 miles of the return trip. The accident vehicle, a 1993 Motor Coach Industries DL-3 55-passenger-capacity motorcoach owned by Chippewa Trails, Inc., was in the lead. It was traveling westbound in the right-hand lane of I-94 at an estimated speed of between 64 and 78 mph when it collided with the bottom of the overturned combination unit about 1:59 a.m.

The motorcoach driver and four passengers were fatally injured. Thirty-five passengers received minor-to-serious injuries, and five passengers were not injured. The truck driver received minor injuries.

The National Transportation Safety Board determines that the probable cause of the truck-tractor semitrailer rollover, the precipitating event in the accident sequence, and the motorcoach's subsequent collision with the truck, was the truck driver's falling asleep at the wheel, drifting from the roadway, and losing control of his vehicle. The truck driver was most likely fatigued because he did not take full advantage of adequate rest opportunities provided to him during his off-duty time and, as a result, obtained inadequate and disrupted sleep prior to the

accident. The motorcoach collided with the overturned truck because there were insufficient visual cues to permit the driver to identify the truck wreckage in time to avoid the collision.

During the investigation, the Safety Board identified the following major safety issues:

- Operator fatigue,
- Fatigue technologies and countermeasures, and
- Collision warning systems.

As a result of this accident investigation, the Safety Board makes two safety recommendations to the Federal Motor Carrier Safety Administration, one safety recommendation to the National Highway Traffic Safety Administration (NHTSA), and one safety recommendation to Whole Foods Market, Inc. The Safety Board also reiterates two safety recommendations to NHTSA.

Factual Information

Accident Narrative

Between 1:58 a.m. and 1:59 a.m.[1] on Sunday, October 16, 2005, an accident comprising two events occurred on Interstate Highway 94 (I-94) near Osseo, Wisconsin. The first event was a single-vehicle rollover of a 2003 Volvo truck tractor and 2004 Great Dane semitrailer combination unit. The second event occurred when a 1993 Motor Coach Industries, Inc., DL-3 55-passenger-capacity motorcoach collided with the wreckage from the first event.

About 7:30 p.m. on October 15, 2005, a 22-year-old truck driver departed Munster, Indiana, on an approximately 436-mile-long trip to Minneapolis, Minnesota, driving a truck-tractor semitrailer operated by Whole Foods Market, Inc. (Whole Foods). By 1:58 a.m., the truck driver had completed about 323 miles of his trip. The combination unit was traveling westbound on I-94 near milepost 85 when it departed the right-hand travel lane and paved shoulder at an approximate 3-degree angle. The Wisconsin State Patrol (WSP) estimated the speed of the truck to be 63 to 69 mph. The unit left the roadway and entered the earthen, sloped roadside. The driver steered to the left, and the combination unit reentered the pavement and overturned onto its right side, sliding to a stop so that it blocked both westbound lanes and shoulders of I-94. The truck driver said that following the overturn, he turned off the ignition and was then thrown into the sleeper berth area by another impact.

About 3 hours before the accident, a group of marching band members from Chippewa High School left the University of Wisconsin near Whitewater on an approximately 225-mile-long trip back to Chippewa Falls, Wisconsin. The group was traveling in four motorcoaches and had completed about 195 miles of the return trip. The accident motorcoach, a 1993 Motor Coach Industries DL-3 55-passenger-capacity motorcoach owned by Chippewa Trails, Inc. (Chippewa Trails), was in the lead. It was traveling westbound in the right-hand lane of I-94 at an estimated speed of between 64 and 78 mph when it collided with the bottom of the overturned combination unit about 1:59 a.m.[2] Several of the motorcoach passengers indicated that they felt a sudden deceleration of the motorcoach just before the impact. No precrash skidmarks were found.

When struck by the motorcoach, the tractor separated from the semitrailer and rotated counter-clockwise into the left side of the motorcoach, so that its left-

[1] Unless otherwise designated, all times in this report are central daylight time.

[2] A conservation of linear momentum in-line collision estimated the speed of the motorcoach to be between 64 and 78 mph. The WSP estimated that the motorcoach's prebraking speed was about 70 mph.

front tire struck the sixth window on the motorcoach, and the semitrailer rotated clockwise into the right side of the motorcoach. The tractor came to rest in the left shoulder and median. The semitrailer slid on its side and came to rest in the right-hand lane. From the impact area, the motorcoach slid forward on its undercarriage and came to rest in the left lane, beyond the truck-tractor semitrailer. Both vehicles sustained extensive damage. There was no postaccident fire.

The motorcoach driver and four passengers were fatally injured. Thirty-five passengers received minor-to-serious injuries, and five passengers were not injured. The truck driver received minor injuries.

At the time of the accident, the weather was clear and the pavement was dry. There was no highway lighting.

See figure 1 for a map showing the accident location. Figures 2 and 3 show the accident scene.

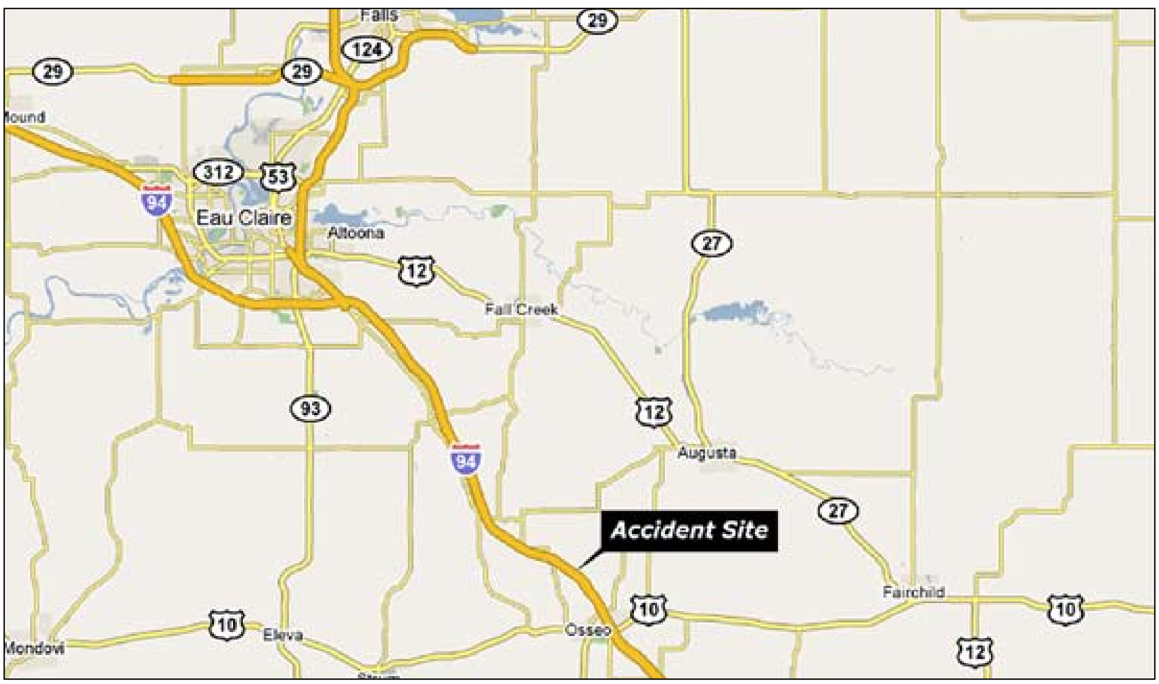

Figure 1. Map showing Osseo, Wisconsin, accident location.

Several State, county, and local public safety agencies responded to the accident. The Trempealeau County Sheriff's Office Communications Center, Eau Claire County Sheriff's Department Communications Center, and city of Osseo Police Department Communications Center coordinated the emergency response of police, fire, and emergency medical service personnel. The WSP served as the primary law enforcement agency and conducted the on-scene investigation.

Figure 2. Accident scene from the air. (Courtesy of the Minnesota State Patrol)

Figure 3. Accident wreckage, looking west. (Courtesy of the Wisconsin State Patrol)

Emergency calls made by motorcoach passengers were received by the communication centers at 2:06 a.m. Responders from the Osseo Volunteer Fire Department were dispatched at 2:07 a.m. and arrived at the accident site at 2:15 a.m. Additional fire department teams arrived at the accident site between 2:25 a.m.

and 2:32 a.m. The first helicopter arrived at 2:28 a.m. The injured passengers and truck driver were transported to seven area medical facilities and arrived between 3:57 a.m. and 4:06 a.m.[3] The area where the accident occurred is rural, and several of the medical facilities were far from the site. Virtually all of the medically trained emergency response personnel were volunteers, and many responded from their homes. Some of those who were medically evacuated by helicopter had to be taken as far as the Mayo Clinic in Rochester, Minnesota.

Rescuers evacuated the fatally and seriously injured passengers from the motorcoach. Many of the passengers evacuated through the emergency window exits located on the left and right sides of the motorcoach at row 7. Passengers who exited through the left side emergency window had to drop about 6 feet to the ground. Band members traveling in another motorcoach from the charter that stopped to assist placed a ladder (provided by the band members from their equipment) at the right side window exit to assist passengers exiting the motorcoach from that window.

Injuries

The truck driver sustained minor injuries, including contusions to the right shoulder and head, as a result of the rollover. The motorcoach driver and four motorcoach passengers sustained fatal injuries. All the fatally injured motorcoach occupants sustained blunt force trauma to the head and upper torso. Five motorcoach passengers received serious injuries, 30 received minor injuries, and 5 did not sustain any injuries (see table 1).

Table 1. Injuries.

Injury severity	Truck driver	Motorcoach driver	Motorcoach passengers	Total
Fatal	0	1	4	5
Serious	0	0	5	5
Minor	1	0	30	31
None	0	0	5	5
Total	1	1	44	46

Title 49 *Code of Federal Regulations* (CFR) 830.2 defines fatal injury as “any injury which results in death within 30 days of the accident” and serious injury as “any injury which: (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.”

[3] The injured passengers and truck driver were transported to Luther Hospital, Gunderson Hospital, Sacred Heart Hospital, Saint Joseph’s Hospital, and Osseo Medical Center, all located in Wisconsin, and the Gillett Children’s Regional Hospital and Mayo Clinic in Minnesota.

Survival Aspects

According to rescue personnel, the motorcoach driver was wearing a lap/shoulder belt, which they cut off after the accident. The motorcoach had no passenger seat belts. The truck driver made conflicting statements regarding his seat belt use.

The four motorcoach passengers who received fatal injuries were seated in the first two rows of seats. All the seriously injured motorcoach occupants were seated in the first four rows of the motorcoach. In the area of the occupant compartment that included the driver's station and first four rows of double passenger seats, the survivable space was reduced by 70 percent. The preaccident seating positions of the motorcoach occupants appear in figure 4.

The accident motorcoach sustained extensive damage to the front of the vehicle with approximately 10 feet of crush. Interior damage extended rearward to between rows 4 and 5. Forward of row 5, passenger injuries ranged from minor to fatal, depending on seating location. Rearward of row 5, passengers either sustained minor injuries or were uninjured.

Despite the severity of the crash, this damage pattern is not unique to this accident. Safety Board investigations of past motorcoach accidents, such as the New Orleans, Louisiana, and Burnt Cabins, Pennsylvania, accidents, show similar damage patterns when the front of the motorcoach is impacted.[4] The Safety Board issued recommendations to the National Highway Traffic Safety Administration (NHTSA) in its 1999 Bus Crashworthiness Report[5] addressing motorcoach crashworthiness and occupant protection (Safety Recommendations H-99-47 and -48, and H-99-50 and -51).[6] These recommendations address not only frontal collisions but also side impact collisions, rear impact collisions, and rollovers. The Safety Board recently reiterated Safety Recommendations H-99-47 and -48 in the Atlanta, Georgia, accident report.[7] In response to these 1999 recommendations and to several subsequent motorcoach accidents, NHTSA published a plan titled

[4] (a) National Transportation Safety Board, *Motorcoach Run-Off-The-Road, New Orleans, Louisiana, May 9, 1999*, Highway Accident Report NTSB/HAR-01/01 (Washington, DC: NTSB, 2001), and (b) National Transportation Safety Board, *Greyhound Motorcoach Run-off-the-Road Accident, Burnt Cabins, Pennsylvania, June 20, 1998*, Highway Accident Report NTSB/HAR-00/01 (Washington, DC, NTSB, 2000).

[5] National Transportation Safety Board, *Bus Crashworthiness Issues*, Highway Special Investigation Report NTSB/SIR-99/04 (Washington, DC: NTSB, 1999).

[6] These recommendations are on the Safety Board's Most Wanted List of Transportation Safety Improvements.

[7] National Transportation Safety Board, *Motorcoach Override of Elevated Exit Ramp, Interstate 75, Atlanta, Georgia, March 2, 2007*, Highway Accident Report NTSB/HAR-08/01(Washington, DC: NTSB, 2008).

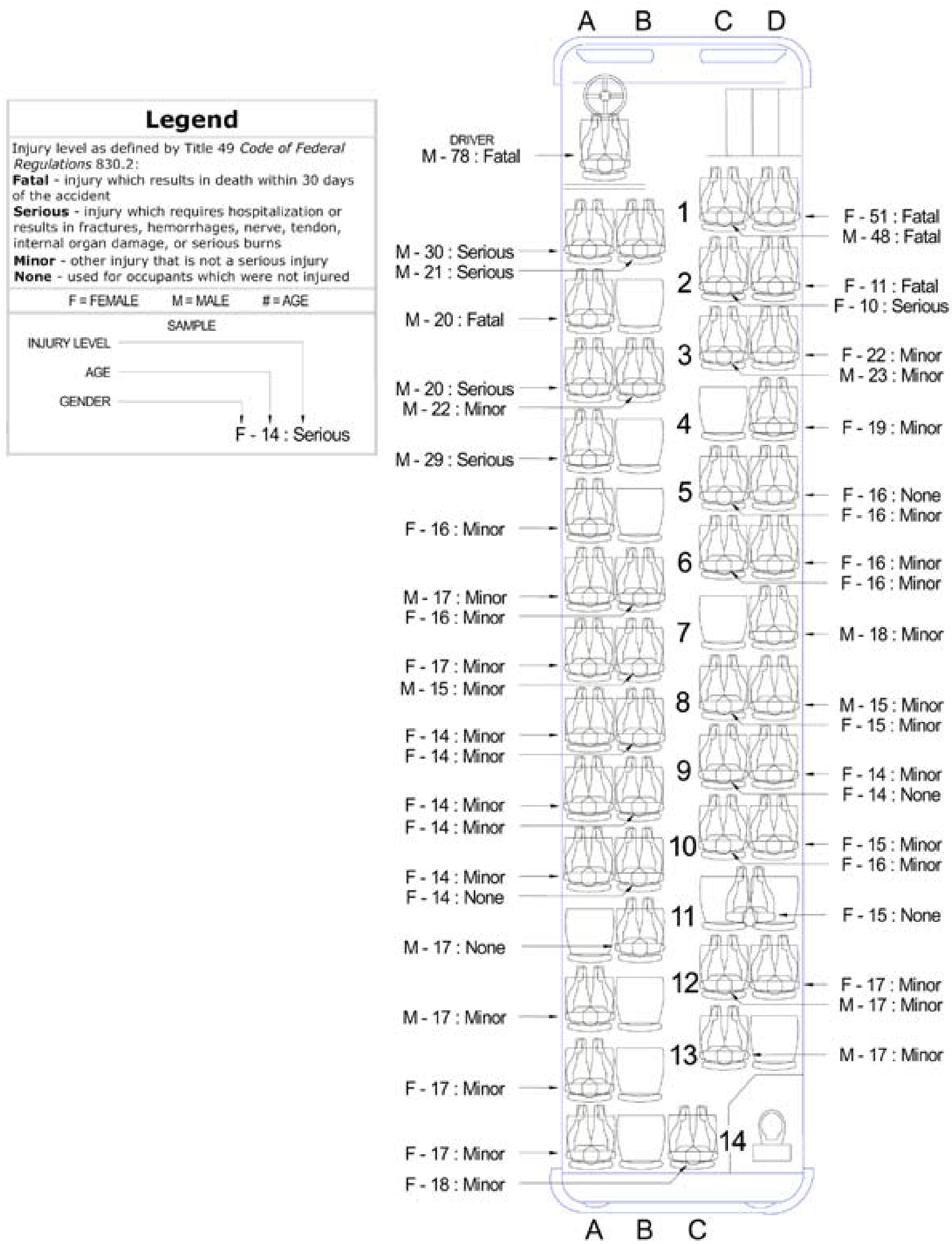

Figure 4. Osseo motorcoach seating chart

"NHTSA's Approach to Motorcoach Safety" (August 6, 2007, NHTSA Docket 2007-28793), which addressed roof strength, occupant protection, flammability, and evacuation.[8]

Vehicles

Truck-Tractor Semitrailer

The 2003 Volvo truck tractor was towing a 2004 Great Dane refrigerated van semitrailer. The overall length of the tractor was 27 feet 6 inches and the width was 7 feet 6 inches. The trailer was 53 feet long, 13 feet 6 inches high, and 8 feet 8 inches wide. Whole Foods weighed an exemplar combination unit and found that the empty weight of the tractor was 19,420 pounds, and the empty weight of the trailer was 21,440 pounds. According to the bill of lading, the weight of the produce cargo loaded on the trailer was 23,200 pounds. The estimated total weight of the accident vehicle was 64,060 pounds.

The Volvo truck tractor was equipped with a Cummins model ISX CM870 diesel engine, which was equipped with an electronic control module (ECM). The engine ECM was capable of capturing limited operating data associated with diagnostic fault information; it was designed to assist repair and maintenance technicians in determining the operating conditions that exist when a system fault occurs. Investigators found one fault condition, "Low Oil Pressure," which was reported as two separate events that could be linked to the vehicle's dynamics occurring at the time of the accident. Examination of the data showed that the low oil pressure condition occurred at 10421:42:22 ECM hours and continued for 16 seconds. This condition was most likely caused by the tractor coming to rest on its side and the driver shutting off the tractor's ignition approximately 16 seconds after the vehicle overturn. The ECM data also indicated that, at the time of the low oil pressure condition, the tractor's road speed was 52 mph and the engine speed was 589 to 596 rpm, which represented an ECM-calculated road speed, based on rotation of the drive train or drive axles at the time of the low oil condition. (This was mechanically inconsistent with the truck's transmission being in 10th gear and the clutch being engaged. The drive train had either been displaced or placed in neutral.) The truck was also equipped with a XATA Xatanet Fleet Management and Communication system. This system was capable of capturing crash-related data; however, it had been inoperative for at least a week before the accident due to a malfunction in the system's hardware and/or software. The truck tractor was not equipped (nor was it required to be) with a dedicated event data recorder.

[8] In support of this plan, NHTSA conducted a full-scale crash test of a 2000 Motor Coach Industries 102EL3 Renaissance motorcoach in December 2007. In February 2008, NHTSA performed roof crush and rollover testing on two 1992 Motor Coach Industries model MC-12 and two 1991 Prevost model LeMirage motorcoaches. NHTSA is conducting followup sled tests to further study occupant protection in motorcoaches. (See Motorcoach Safety Research Motorcoach Crash Test, Docket Number NHTSA-2007-28793, January 23, 2008, and August 14, 2008, Memorandum to Docket 2007-28793.)

Data from the truck driver's personal Garmin global positioning system (GPS) were also examined. For almost the last 5.2 miles of the trip, the tractor's speed was fairly constant and ranged from 66 to 70 mph, with an average speed of 68 mph. The tractor's precrash heading was 306 degrees. During the last 0.1 mile of travel, the GPS data show a vehicle heading from 305 degrees to 310 degrees, which switched to a heading of 212 degrees, as well as the vehicle's decelerating.

The tractor sustained most of its damage to the right side and underside in the area of the third axle. The right side of the tractor cab was scraped and dented. The sidewalls of the right side tires on both axles were scraped and both wheel rims were bent inward. The left side of the diesel fuel tank was punctured at its aft end. The right side headlight assembly was broken. The windshield and right side window were broken out from the tractor cab. The left side headlight assembly and the left side window remained intact. The tractor frame was bent downward behind the tractor cab and forward of the second axle. (See figure 5.)

Figure 5. Accident tractor.

The trailer sustained the majority of its damage to its right side and underside in the area of the landing gear and fuel tank mountings. The landing gear was detached from the bottom of the trailer. The fuel tank for the refrigerator trailer was also detached and had numerous cracks and punctures. The fifth wheel plate, which was detached from its mounting on the tractor, remained attached to the trailer kingpin. The right side and the roof of the trailer were deformed. (See figure 6.) The left side of the trailer was mostly undamaged, with the exception of the area near the fuel tank mounting, where there was some outward bending to the bottom of the trailer.

Figure 6. Accident semitrailer (right side).

The truck tractor and semitrailer were equipped with pneumatic braking. All brakes were found to be within the pushrod travel limits specified by the Commercial Vehicle Safety Alliance (CVSA) North American Standard Out-of-Service Criteria and in good condition.

At the time of the postaccident inspection, the high-low gear range selector was found in the high position, and one of the synchronizers appeared to be engaged into the gear that supplies the 5th and 10th gears for the transmission, indicating that the tractor transmission had been in 10th gear at the time of the accident. The steering system, tires, and suspension systems were found to be functional.

The left and right headlight assemblies of the tractor consisted of five light bulbs: a low-beam bulb, a high-beam bulb, a daytime running and turn signal combination bulb, a side marker bulb, and a fog light bulb. The tractor's left and right headlight assemblies and its left and right taillights were examined at the Safety Board Materials Laboratory. Results appear in the "Testing and Research" section.

The back of the trailer had light-emitting diode (LED) lamp assemblies and retroreflective tape, in compliance with Federal Motor Vehicle Safety Standard (FMVSS) 108.[9]

Motorcoach

The 1993 Motor Coach Industries DL-3 55-passenger-capacity motorcoach was 45 feet long, 11 feet 4 inches high, and 98 inches wide in the front and 102 inches wide in the rear. The motorcoach odometer reading was 343,618.5 miles. It was equipped with a Detroit Diesel, Series 60, 12.7-liter engine, and an Allison HT-740-D transmission. The motorcoach engine was equipped with an ECM, but it was not designed as an event data recorder and did not capture any crash-related data.

As shown in figure 7, the motorcoach sustained extensive damage to its front end. The front of the motorcoach was pushed rearward to about the third row of passenger seats. The front axle was pushed back and upward such that the front tires were not in full contact with the ground. The floor of the motorcoach adjacent to the front axle wheel wells was buckled upward. The seats on the right side, in the area of the front axle wheel wells, were pushed upward and out the right side of the windows.

Figure 7. Motorcoach accident damage.

[9] FMVSS 108 specifies the requirements for original and replacement lamps, reflective devices, and associated equipment.

Most of the windows aft of the front axles were intact. The fourth window from the back on the left side was broken and appeared to have tire marks on it. A dual set of tire marks was found at the right rear side of the motorcoach.

Portions of the steering and suspension systems were found to be damaged due to crumpling at the front end of the motorcoach, but no abnormalities were discovered. Postaccident inspection found the systems to be functional, and all indications showed that they were working appropriately before the crash.

At inspection, the right-front axle tire was flat. The air pressure measurements for the other tires ranged from 88 to 96 psi. The tread depths of the tires were also measured, and they ranged from 3/32 to 16/32 inch.

The motorcoach was equipped with four headlight lamps (sealed beam units), two on each side. The outboard headlights operated as the low-beam headlights, and the inboard headlights operated in conjunction with the low-beam headlights to provide high-beam illumination. During the original inspection of the accident motorcoach, only two of these lamps, one from each side, were available for postaccident examination. The Safety Board Materials Laboratory examined the motorcoach's lighting following the accident. Results of the examination appear in the "Testing and Research" section.

The motorcoach was equipped with a pneumatic braking system, which consisted of 14.5- by 6-inch drum/shoe brakes on the steer axle, 14.5- by 10-inch drum/shoe brakes on the drive axle, and disc brakes on the tag axle.[10] Several air hoses toward the front of the motorcoach, near the instrument panel, and at the floor pan area near the application pedals were severed, prohibiting postaccident assessment of the overall pneumatic system. Air reservoirs were located aft of the steer axle and toward the first cargo bay of the motorcoach. The air reservoirs appeared to be damaged but not punctured. The brake pads and drums on the steer and drive axles did not show signs of excessive wear.

As part of the normal investigative protocol, the motorcoach's brakes were examined and tested. The results, summarized in table 2, indicated that the brakes on the drive axle of the motorcoach were out of adjustment. This would have placed the motorcoach out of service according to the CVSA out-of-service criteria. The automatic slack adjusters[11] on the drive axle were dated "1993" and had been on the motorcoach for over 12 years.

[10] The front axle of a motorcoach is referred to as the steer axle, and it is where steering input is applied. The second axle is referred to as the drive axle; it is a dual-wheel axle where torque from the engine is transferred to the wheels. The third axle is a load-bearing, undriven axle, and it is referred to as the tag axle.

[11] Safety Recommendations H-06-1 and -7 concerning automatic slack adjusters are discussed in this report's "Analysis."

Table 2. Motorcoach brake adjustments.

Axle	Brake type	Automatic slack adjuster length (inches)	Push rod travel (inches)	Adjustment limit (inches)[a]
Left steer	24	6	1 1/2	1 3/4
Right steer	24	6	1 3/4	1 3/4
Left drive	30L DD3	7	2 7/8	2 1/4[b]
Right drive	30L DD3	7	2 3/4	2 1/4[b]
Left tag	16	5 1/2	1 3/4	1 3/4
Right tag	16	5 1/2	1 5/8	1 3/4

[a]CVSA *North American Standard Out-of-Service Criteria*, April 2005 edition, Braking System – Part 2, Section 1.
[b]Out of adjustment, based on CVSA criteria.

The total braking efficiency for the motorcoach was calculated to be 54 percent, resulting in a maximum deceleration rate of 0.369 *g*.[12] If all the brakes had been within adjustment and adjusted to achieve the maximum amount of brake force, the preimpact deceleration rate could have been 0.587 *g*, which would have resulted in a braking efficiency of 85 percent.

Driver Information

Truck Driver

The 22-year-old male truck driver possessed a suspended Indiana class A commercial driver's license (CDL) with no restrictions or endorsements. The CDL was issued on February 15, 2005, and had an expiration date of January 2010. The license was suspended on September 21, 2005, for failure to pay a speeding citation received on July 3, 2005.[13] The driver's Indiana driving record showed two additional speeding violations in noncommercial vehicles in 2001.

The truck driver possessed a valid medical certificate issued on September 22, 2005, which had an expiration date of September 22, 2007. A review of the truck driver's medical examination revealed that he reported no adverse medical history or use of medications, and the physician's examination disclosed no disqualifying conditions.[14] The truck driver was not required to wear corrective lenses while driving.

[12] Brake efficiency calculations are based on a 100-psi brake application and a surface friction value of 0.68, without taking into account *brake lag time*, which is the time it takes for air pressure to be delivered and applied to the brakes.

[13] The driver was cited for traveling 76 mph in a 55-mph zone. He was operating a noncommercial vehicle.

[14] Safety Recommendations H-01-19 and -20 concerning medical oversight are discussed in this report's "Analysis."

The truck driver had 7 months of professional truck driving experience, excluding training. Before he became a truck driver, Whole Foods had employed him as a dockworker.

Work/Rest History. According to the WSP's interview with the driver, he reported that he worked 50 to 55 hours per week. His normal Whole Foods work schedule was to pick up a load on Thursday night for Friday delivery, on Saturday night for Sunday delivery, and on Monday night for Tuesday delivery. On the accident trip, he was to pick up the load in Indiana and bring it to Minnesota; half the load was destined for St. Paul and the other half for Lake Calhoun. He had been driving this route for about 3 weeks.

The truck driver's 72-hour history was reconstructed using data provided by the WSP.[15] The truck driver had not completed daily logs since October 11, 2005, five days before the accident; his activities were reconstructed using his statements to the WSP, notes and other paperwork found in the truck tractor, and information provided by people who observed the truck driver before he left Indiana on the accident trip.

On Thursday, October 13, he arrived at the Whole Foods Midwest distribution center around 7:45 p.m. to pick up a load for delivery in Minnesota. He began driving about 8:45 p.m. and continued driving through the night. Notes written by the truck driver, found postaccident in the truck, indicate that he slept in the sleeper berth of his truck from 9:00 a.m. to 4:30 p.m. (7.5 hours) on Friday, October 14. He began driving at 4:30 p.m., returning to Indiana, where he went off duty about 10:30 p.m.

The driver spent the later hours of Friday, October 14, and the early morning hours of Saturday, October 15, socializing at a restaurant and bar with friends. During this period, he consumed alcoholic beverages; the amount of his consumption is not known. The driver said he went home about 2:00 a.m., but further investigation by the WSP revealed that the driver did not return home until 6:00 a.m. The only remaining uninterrupted period he had in which to obtain extended sleep was from 6:00 a.m. to 10:57 a.m. Cellular phone records indicate that the driver participated in numerous phone calls, beginning at 10:57 a.m. and ending at 5:04 p.m.[16] The longest interval between calls on the driver's cellular phone during this period was less than 2 hours (between 12:07 p.m. and 2:03 p.m.). Also on October 15, he visited a friend and stopped at a drugstore,[17] where he purchased an energy drink and snacks, before he traveled to the Whole Foods Midwest distribution center.

The truck driver told the WSP that he arrived at the Whole Foods Midwest distribution center about 7:00 p.m. on October 15, conducted a pretrip inspection of the truck while it was loaded, and departed on the accident trip about 8:00 p.m.[18]

[15] The truck driver, through his attorney, declined to be interviewed by Safety Board investigators following the accident.

[16] Outgoing phone calls were made at 10:57 a.m., 11:20 a.m., 11:23 a.m., 12:04 p.m., 12:07 p.m., 3:17 p.m., 3:22 p.m., 3:33 p.m., and 5:04 p.m. There was an incoming phone call at 2:03 p.m.

[17] A receipt from the drugstore was recovered from the truck tractor; it showed a time of 5:29 p.m.

[18] Handwritten notes found in the truck indicate the driver left at 7:30 p.m.

The driver stated that he drove for about an hour, stopped briefly for a soda and to use the restroom, and then drove continuously until the accident occurred. Police subsequently determined that the truck driver made a stop of 39 minutes duration in Tomah, Wisconsin, about 12:30 a.m. Figure 8 shows the reconstruction of the truck driver's work/rest history.

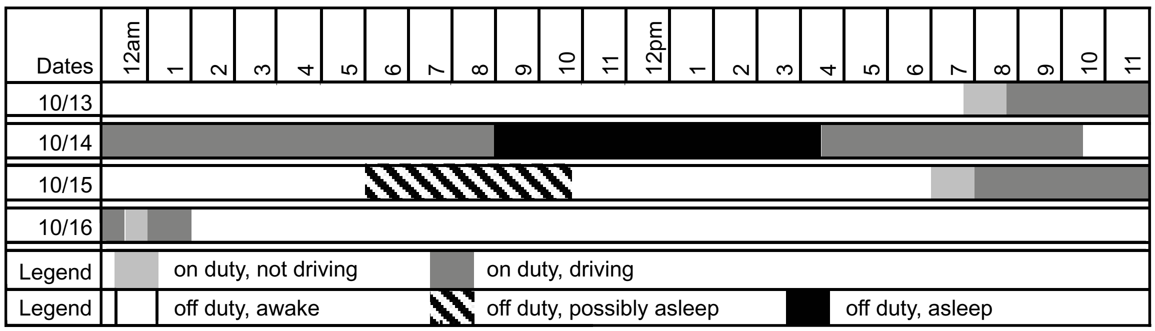

Figure 8. Truck driver's work/rest history.

Cellular phone records indicated the driver had not been using his cellular telephone at the time of the accident.

Truck Driver Interview. Following the accident, the WSP interviewed the truck driver. He stated that at the time of the accident, he was traveling 66 mph and was moving the vehicle onto the shoulder to stop to urinate along the roadside. He said he disengaged the cruise control and reached to the left of the steering wheel on the dashboard to activate the truck's hazard flashers while pulling over to the shoulder. He said that the right steer tire "grabbed gravel," and that he felt the truck "jerk over." He said he continued to brake and tried to regain control to stop, but the truck began sliding down the road on its right side. The driver said that when the truck came to rest, he used the key to turn off the ignition and was then thrown into the sleeper berth of the tractor by another impact. The driver climbed out of the tractor through an opening in the windshield.

The truck driver said that as he slowed the truck before the loss of control, he observed no other traffic on the highway and that the traffic had been light. He said that as he lost control of the truck, he saw a reflectorized post on the roadside and felt that the post may have blown the right steer tire and contributed to the loss of control.

The driver reported that he smokes cigarettes, drinks alcoholic beverages, and does not use stimulants to stay awake. He said that during work time he always drove the truck involved in the accident and that he was not tired at the time of the accident. The driver did not report having any mechanical problems with the truck on the night of the accident.

Witness and WSP Statements. A witness who was traveling on I-94 westbound said she observed the truck-tractor semitrailer come off a ramp and proceed westbound.[19] The witness said she moved her vehicle to the left lane, passed the tractor semitrailer, and then moved back into the right lane. The tractor semitrailer passed her in the left lane. The witness said, "As he passed me, he straddled the line between the left lane and the far left lane, which exited to the left—then weaved." She also said the tractor semitrailer was not "driving as straight as I was comfortable with," and she slowed her vehicle's speed to "get away from him."

Another witness stated that he observed a Whole Foods truck-tractor semitrailer in the vicinity of Madison, Wisconsin (about 150 miles from Osseo). He said he followed the truck and observed it "driving erratically." The witness said the truck drifted from the right-hand lane onto the shoulder and then back into the right-hand lane. He said he considered passing the truck but rejected the idea. In the area of Wisconsin Dells, Wisconsin (about 100 miles from Osseo), the witness saw several charter buses traveling westbound on the highway. The truck and the witness passed the buses and continued toward Osseo. He said that about 4 miles east of the Osseo exit, he saw the truck drift onto the shoulder and then drive back into the right-hand lane. The witness said he exited at the Osseo exit, purchased a cup of coffee, and reentered the highway. As he was traveling westbound, a State patrol car with emergency lights on passed him. The witness subsequently came upon the accident involving the motorcoach and the Whole Foods truck. He stopped to assist the injured.

The WSP trooper who had custody of the truck driver following the accident stated that he did not observe any signs of intoxication on the part of the driver. He also said that he did not detect any odor of alcohol from the truck driver. The trooper did not conduct a breathalyzer test of the truck driver.

Motorcoach Driver

The motorcoach driver was a 78-year-old male who had 59 years of professional experience driving large trucks, school buses, and motorcoaches. He worked for Chippewa Trails for 13 years, during which time he was a full-time school bus driver and a part-time motorcoach driver. He possessed a valid Wisconsin class A CDL with a restriction requiring corrective lenses while driving; the CDL had hazardous materials, tank truck, passenger, and school bus endorsements. The CDL had an expiration date of May 4, 2008. The motorcoach driver's driving record showed three traffic violations, including two property damage accidents (one on April 27, 2001, in a commercial vehicle, and one on January 5, 2003, involving a noncommercial vehicle) and a speeding violation in a noncommercial vehicle (15 mph over the speed limit) on August 14, 2003.

[19] The witness could not recall the exit at which the truck reentered the roadway. (The WSP found that the truck driver had taken a break in Tomah, Wisconsin.)

The motorcoach driver had a valid medical certificate issued on November 4, 2004. The medical certificate issued to the driver indicated an expiration date of November 4, 2006.[20] The medical examination report said the motorcoach driver did not report any adverse medical history or use of medications, and the physician's examination disclosed no disqualifying conditions. The medical examiner reported that the driver's visual acuity met standards only when he was wearing corrective lenses.

The motorcoach driver's personal ophthalmologist examined the driver on June 17, 2005. The driver had a distant visual acuity (uncorrected) of slightly better than 20/50 in his right eye, 20/50 in his left eye, and slightly worse than 20/40 in both eyes together. His best corrected visual acuity was just under 20/25 in the right eye and just under 20/20 in the left eye. The driver also had some very early cataract formation in both eyes.[21] The motorcoach driver's family said the driver used his eyeglasses primarily for reading. Investigators found the motorcoach driver's eyeglasses in his bag on the motorcoach during the on-scene investigation.

At the time of the accident, the motorcoach driver was in possession of a two-way radio that he had used throughout the trip to communicate with the driver of the fourth motorcoach in the queue. According to the driver of the fourth motorcoach, there was no radio communication at the time of the accident.

Work/Rest History. The motorcoach driver was off duty from school bus driving for the 2 days prior to departing for the Chippewa High School marching band charter. The motorcoach driver's activities for the 4 days preceding the accident were reconstructed using information provided by the driver's daily logs,[22] the driver's family, and other motorcoach drivers on the trip (see figure 9). The motorcoach driver's spouse said that on October 13, 2005, he went to bed at 10:00 p.m. and slept until 8:00 a.m. the next morning. The driver reported to work at 2:30 p.m. on Friday, October 14, and conducted a pretrip inspection. At 5:30 p.m., he began driving and drove until 8:15 p.m., when he stopped the motorcoach at a rest area. According to another motorcoach charter driver, they resumed driving about 8:40 p.m. and arrived at Oregon Middle School at 9:30 p.m., where they unloaded the bus. The other driver said they drove to Middleton, Wisconsin, checked into the hotel, and had a meal. They returned to the hotel about midnight. The next morning, Saturday, October 15, the motorcoach drivers had breakfast around 8:00 a.m. and conducted pretrip inspections of the motorcoaches. At 11:00 a.m., the driver returned to Oregon Middle School and had lunch with the band members and other drivers. After lunch, the drivers rested in the motorcoaches. The buses were loaded at 3:15 p.m. and, about a half-hour later, the group left for Whitewater,

[20] The expiration year on the medical certificate was mistakenly listed as 2006; it should have been 2005. The medical examination report for the certificate showed an expiration date of November 4, 2005. An examining physician can request that a driver be checked more frequently. In this case, the examining physician cited the driver's age as the reason for the 1-year limit on the validity of the medical certificate.

[21] *Cataracts* are a clouding of the lens in the eye.

[22] The bus driver had completed his daily logs through 10:30 p.m. on October 15, 2005, about 3 1/2 hours before the accident.

Wisconsin. They arrived at Whitewater about 5:00 p.m., had dinner, opened the motorcoaches so the band could prepare, and watched the band's performance. At 10:00 p.m., they began loading the buses and departed Whitewater around 11:00 p.m., to return to Chippewa Falls.

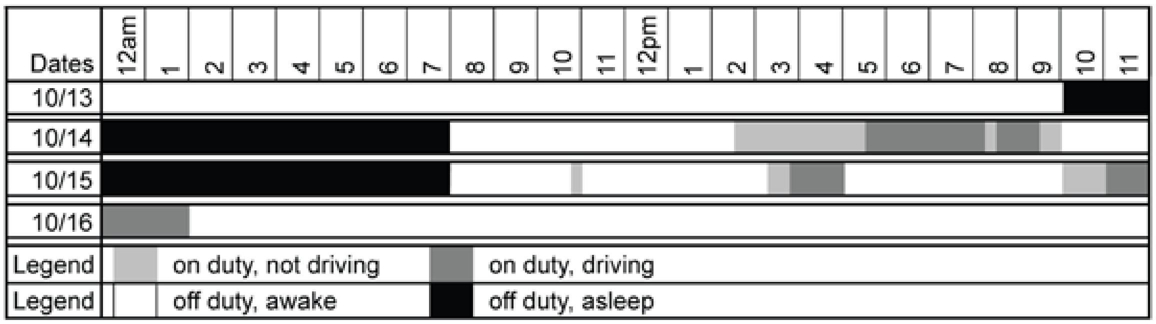

Figure 9. Motorcoach driver's work/rest history.

Highway Information

General

The accident occurred on I-94 westbound at milepost 84.9, approximately 3 miles northwest of the exit 88 off ramp to U.S. Route 10. The accident site was about 19 miles southeast of the city of Eau Claire in Eau Claire County, Wisconsin. I-94 is classified as a rural principal arterial road.[23]

I-94 in the vicinity of the accident was constructed by the Wisconsin Department of Transportation (WISDOT) in 1965.[24] It is a divided four-lane asphalt roadway that runs east and west. The measured width of the paved portion of the westbound roadway is approximately 39 feet, which consists of an 11-foot-wide right shoulder, two 12-foot-wide main travel lanes, and a 4-foot-wide left shoulder. There is a 2-foot-wide gravel shoulder beyond the paved right shoulder and a 3-foot-wide gravel shoulder beyond the paved left shoulder. The paved portion of the eastbound roadway is identical to the westbound roadway.

The westbound and eastbound lanes are divided by a 60-foot-wide depressed earthen median, with a 24-foot-wide paved asphalt median crossover immediately opposite the accident site. I-94 has no artificial highway safety

[23] According to the American Association of State Highway and Transportation Officials (AASHTO), rural principal arterials comprise the interstate system and most rural freeways. They also include other multilane roadways and some two-lane highways that connect urban centers. Minor rural arterials link urban centers to larger towns and are spaced to provide a relatively high level of service to developed areas of a State.

[24] See *State of Wisconsin State Highway Commission of Wisconsin, Plan and Profile Proposed, Eau Claire—Tomah Road, Foster—South County Line Section, I-94 Eau Claire County*, Project I-94-2(37)83, September 24, 1965.

lighting in the vicinity of the accident. As specified in the Federal Highway Administration's (FHWA) *Freeway Management and Operations Handbook*, this section of I-94 does not meet the minimum warrant criteria that would justify the installation of lighting.

The posted speed limit for I-94 in the vicinity of the accident is 65 mph. On October 19, 2005, between 12:15 p.m. and 1:15 p.m., the Safety Board and WISDOT conducted a speed study on I-94 at the Ryder Road overpass near milepost 85.7. The 85th percentile speed was 73 mph for passenger cars and 68 mph for tractor-semitrailers. The grade of the westbound lanes of I-94 from the apex of the crest vertical curve to the accident site was -3.1 percent (see figure 10), and this distance was approximately 2,300 feet. The crest vertical curve consisted of a negative 3.1-percent downgrade slope and a positive 2.4-percent upgrade slope. The two grades were connected by a 1,400-foot-long crest vertical curve. The crest vertical curve on the westbound lanes of I-94 conformed to a 70-mph design speed, in accordance with AASHTO criteria.

Figure 10. Accident site. (Courtesy of the Minnesota State Patrol)

I-94 has rumble strips[25] on the right and left shoulders of its westbound lanes. Each rumble strip is 16 inches long and 7 inches wide. The rumble strips are spaced 5 inches apart. The depression depth of the rumble strips into the asphalt shoulder is approximately 0.5 inch. The rumble strips on the right shoulder are

[25] *Rumble strips* are raised or grooved patterns in the pavement. Traveling over the rumble strips causes the vehicle to vibrate, which alerts the driver.

offset from the solid white line by 2 feet 6 inches (see figure 11). The rumble strips on the left shoulder (adjacent to the median) are offset from the solid yellow lines by 6 inches.

Figure 11. Rumble strips along the right shoulder of westbound I-94.

WISDOT provided the average daily traffic (ADT) data for I-94 in the vicinity of the accident, which is shown in table 3. Table 4 shows the 2003 vehicle classification data for I-94 at milepost 93.

Table 3. ADT on I-94 in the vicinity of the accident.

Year[a]	Westbound ADT (vehicles per day)	Eastbound ADT (vehicles per day)	Total ADT (vehicles per day)
1997	11,300	11,100	22,400
1998	13,200	12,500	25,700
1999	13,500	12,800	26,300
2001	15,000	15,000	30,000
2004	11,700	12,200	23,900

[a] WISDOT did not perform ADT counts for this part of I-94 in 2000, 2002, or 2003.

Table 4. Vehicle classification data for 2003 for I-94 at milepost 93.

Vehicle type	Percentage of vehicle class
Motorcycles	0.2
Passenger cars, pickups, and panel trucks (2-axle,4-tire)	57
Buses	0.9
Single-unit trucks (2 axles or more – 6 tires or more)	2.6
Single trailer trucks	37.1
Multitrailer trucks (5 axles or less)	2.2
Total	100

WISDOT provided information on accidents occurring on westbound I-94 within a 5-mile radius of the accident site from 2000 through August 2005. During this period, 182 accidents occurred in this area, 2 of which were fatal. (The two fatal accidents occurred in commercial vehicles during daylight hours.)

Tire Marks

The tractor semitrailer left the road at an angle of 3.45 degrees and was in contact with the rumble strips for 190 feet.

Measurements of the tire furrow marks, shown in figure 12, were taken from where the truck departed and returned to the roadway. It is 340 feet from the first visible tire furrow mark on the earthen shoulder, adjacent to the rumble strip, to the point at which the tire began to curve back toward the pavement. The second furrow mark, which began to curve back to the pavement and was farthest from the edge of the pavement, was about 368 feet from the first visible tire furrow mark observed on the earthen shoulder adjacent to the rumble strip.

Motor Carrier Information

Whole Foods

General. The truck-tractor semitrailer was operated by Whole Foods Market Group, Inc., dba Whole Foods Market, Inc. Whole Foods is an interstate, authorized for hire, private property carrier of general freight, produce, and refrigerated foods. The company has 48-State and Canadian authority. Its U.S. Department of Transportation (USDOT) number is 651645, and its MC number is 306991.[26]

[26] A USDOT number is a unique identifier used to track safety information collected during audits, compliance reviews, crash investigations, and inspections. The MC number defines the type of operation the company may run, the cargo it may carry, and the geographic area in which it may operate.

Figure 12. Osseo truck tire furrow marks.

Company records for 2004 indicate the most recent annual miles traveled by Whole Foods as 1.885 million miles. In the previous year, Whole Foods had two recordable accidents, and its accident rate per million vehicle miles traveled was 1.061.[27]

Whole Foods has 10 distribution centers across the United States. Each distribution center operates independently from the parent organization with respect to personnel issues such as driver training and oversight. The motor carrier's Midwest distribution center, which has been in operation since the 1980s, employed the accident driver.[28] The Midwest region employed 26 company drivers. The Midwest truck fleet consisted of 19 truck tractors and 19 semitrailers.

Compliance Review. On October 18, 2005, two days after the accident, the FMCSA conducted a compliance review of the Midwest distribution center of Whole Foods, which had never before undergone a compliance review. Although the Whole Foods Midwest distribution center received a satisfactory rating, the compliance review indicated a conditional rating in the driver regulatory area. Violations noted in the compliance review included

[27] The Federal Motor Carrier Safety Administration (FMCSA) has determined that motor carriers with accident rates of 1.50 or greater are deficient in the accident area of the compliance review rating process.

[28] The primary operating area of the Whole Foods Midwest region includes Illinois, Michigan, Minnesota, Missouri, Nebraska, Wisconsin, and the Central provinces of Canada.

- Failing to request information (background inquiry) from a previous employer,
- Failing to inquire about a preemployment drug and alcohol test that resulted in a positive or a refusal to take a test in the previous 2 years,
- Using a USDOT custody and control form for a non-USDOT test,
- Using a driver before the motor carrier had received a negative preemployment controlled substance test,
- Failing to provide employees a written policy on misuse of alcohol and controlled substances,
- Failing to maintain a 1-year accident register,
- Using a driver with incomplete or no employment application,
- Failing to maintain inquiries into a driver's employment record in a driver qualification file,
- Requiring or permitting a property-carrying commercial motor vehicle (CMV) driver to drive more than 11 hours,
- Requiring or permitting a property-carrying CMV driver to drive after the end of the 14th hour after coming on duty,
- Requiring or permitting a property-carrying CMV driver to drive after having been on duty more than 70 hours in 8 consecutive days,
- Making false reports of records of duty status,
- Failing to require a driver to prepare a record-of-duty status,[29] and
- Failing to preserve a driver's record-of-duty status for 6 months.

The only violation serious enough to affect a portion of the motor carrier's compliance rating was "using a driver before the motor carrier has received a negative preemployment controlled substance test." The compliance review showed no other infringements of critical or acute regulations.[30]

Roadside inspection data for the year before the accident indicated that the Whole Foods Midwest distribution center underwent five vehicle inspections, and no vehicles were placed out of service. One of the eight drivers inspected was placed out of service (12.5 percent).[31]

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[29] Safety Recommendations H-77-32, H-90-28 and -48, H-98-23 and -26, and H-07-41 and -42 concerning record-of-duty status are discussed in this report's "Analysis."

[30] A critical regulation identified by the FMCSA is one for which noncompliance relates to management and/or operational controls. An acute regulation is one for which violation requires immediate corrective action, regardless of the overall safety posture of the motor carrier. See 49 CFR Part 385 Appendix B, Subpart V11, "List of acute and critical regulations."

[31] For FY 2006, the national large truck out-of-service rate was 23.7 percent, and the truck driver out-of-service rate was 7 percent.

Driver Training. Whole Foods stated that its experienced drivers train the new drivers. During the first week, new drivers ride with an experienced driver. The new driver rotates as co-driver among six drivers during the second week of training. After the second week of training, the driver trainers meet to discuss the new hire's abilities behind the wheel. Beginning the third week or later, a new hire is released to drive without a trainer on local routes. New hires begin driving non-local trips once the carrier has determined the driver is capable of the longer routes. The accident driver received about 280 hours of co-driving experience during his training.

Drivers also receive in-house training on vehicle inspection and maintenance procedures. Whole Foods provides its drivers with publications addressing driver safety, rules and regulations, safety trends, braking, rest and fatigue, and driving procedures.

Drug and Alcohol Testing. The random drug and alcohol testing program for the Whole Foods Midwest distribution center is handled at a local clinic in Munster, Indiana. As required by 49 CFR 382.305, Whole Foods annually conducts random controlled substance tests on 50 percent of its drivers and alcohol tests on 10 percent of its drivers. The accident driver had been a dock employee for Whole Foods before becoming a truck driver. The Midwest distribution center failed to conduct a preemployment drug test before allowing the accident driver to become a driver and was cited for this violation in the postaccident compliance review.

Maintenance. The 2004 tractor was leased to Whole Foods by Ryder Truck Service, which was responsible for tractor maintenance. Records showed that repairs were completed in September 2005 and included a turn signal light bulb replacement, a cooling system inspection due to a leak, a windshield wiper blade replacement, a glad hand seal replacement, a fan belt replacement, and an adjustment to the clutch pressure plate.

Chippewa Trails

General. Chippewa Trails, Inc., is a family-owned business that began operations in 1902. It is an interstate, for-hire passenger carrier with 48-State authority. It operates under USDOT number 141769 and MC number 141993. At the time of the accident, Chippewa Trails had three operating segments: trucking, school bus, and motorcoach operations.[32] The trucking operation included five dump trucks and a tractor-semitrailer. The school bus division was represented by Chippewa Yellow Bus Company. It operated 58 school buses on 116 school routes under contract with Chippewa Falls School District. The motorcoach operation had 12 motorcoaches and included charters with the Chippewa Falls School District, the Eau Claire School District, and the University of Wisconsin. Other charter services included providing transport to a local casino, weekend sporting events, and the Mall of America. Chippewa Trails employed 12 full-time motorcoach drivers and

[32] Following the accident, Chippewa Trails sold the motorcoach business.

20 part-time drivers for its trucking and school bus divisions. The accident driver drove school buses and motorcoaches.

The annual total miles traveled by Chippewa Trails (for all its operations) in 2004 was 787,970. This accident was the only reportable accident for Chippewa Trails for the 13 months beginning October 2004.

The accident trip was a charter for the Chippewa High School marching band. The accident motorcoach and three others from three different companies were used for the band charter trip.

Compliance Reviews. In September 2000, the FMCSA conducted a compliance review of the operator, and Chippewa Trails received a satisfactory rating. The FMCSA conducted a postaccident compliance review on October 18, 2005, which resulted in a satisfactory rating. The FMCSA noted the following violations during the 2005 compliance review:

- Failing to maintain records for 5 years,
- Using a driver without a currently valid motor vehicle operator's license or permit,
- Using a driver who has not completed and furnished an employment application,
- Requiring or permitting a passenger-carrying CMV driver to drive more than 10 hours,
- Having a false report of record-of-duty status,
- Failing to keep records of inspection, repair, and maintenance indicating their date and nature,
- Failing to keep records on tests conducted on pushout windows, emergency doors, and emergency door interior marker lights,
- Requiring or permitting the operation of a motor vehicle declared "out of service" before repairs were made,
- Failing to maintain completed inspection forms for 12 months from the date of inspection at the motor carrier's principal place of business, and
- Failing to retain vehicle inspection reports for at least 3 months.

Chippewa Trails received an acute violation for operating a motor vehicle declared out of service before repairs were made. No critical violations were noted. The carrier's management told investigators that it has corrected the violations noted in the postaccident compliance review. No fines were assessed against Chippewa Trails.

In the 12 months before the accident, Chippewa Trails underwent 1 driver roadside inspection, with no out-of-service violations, and 11 vehicle roadside inspections, with 3 vehicles being placed out of service (27.2 percent).[33]

Driver Training. Voluntary annual driver retraining was conducted in logbook entry, motorcoach operations, special driving conditions, and pretrip inspections. Additional training was provided at a vocational technical institute, and the WSP conducted safety seminars with the carrier.

Drug and Alcohol Testing. Chippewa Trails contracted out its drug and alcohol testing program for drivers, and the program was conducted in accordance with Federal regulatory requirements. The 2005 FMCSA compliance review indicated no violations in this area.

Maintenance. At the time of the accident, Chippewa Trails conducted its own vehicle maintenance and employed six full-time mechanics. State police had inspected the maintenance facility in July 2005 and placed three motorcoaches, including the accident motorcoach, out of service. The inspection report for the accident motorcoach stated that the drive axle brakes were out of adjustment 2 5/8 inches on the left and 2 1/2 inches on the right.[34] The motor carrier attempted to solve the problem by adjusting the automatic slack adjusters. Records also revealed that one motorcoach was used on a charter trip without Chippewa Trails documenting repairs or requesting a followup inspection as required.[35]

Meteorological Information

On October 16, 2005, the 1:56 a.m. weather observation at Chippewa Valley Regional Airport, approximately 3 miles north of Eau Claire, Wisconsin, recorded a temperature of 35º F, winds calm, visibility unrestricted at 10 statute miles, sky clear, and dew point temperature of 33º F. No precipitation was reported within 24 hours of the accident. No National Weather Service advisories or travel advisories had been issued for the area.

Astronomical data at 1:59 a.m. indicated that the moon was 38.3 degrees above the horizon at an azimuth of 228.8 degrees, with 0.98 of the moon illuminated.[36] This would have placed the moon off the left shoulder of westbound I-94 drivers.

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[33] For FY 2006, the national bus driver out-of-service rate was 4.0 percent and the bus out-of-service rate was 9.0 percent.

[34] These out-of-adjustment measurements exceed the 2 1/4 inches permitted under the CVSA criteria.

[35] *Wisconsin Motor Bus Equipment* 330.06.

[36] At new moon, none (0.00) of the moon is illuminated; at first and last quarter, half (0.50) of the moon is illuminated; and at full moon, the whole (1.00) moon is illuminated.

Testing and Research

Toxicological Testing

Truck Driver. The law enforcement personnel on the scene of the accident indicated no cause, based on the truck driver's behavior or physical condition following the accident, to suspect that the driver was impaired by alcohol or drugs. The truck driver was taken to Luther Hospital in Wisconsin for treatment of his injuries. At 4:29 a.m., a WSP trooper arrived to interview the driver. After this interview, the trooper called Whole Foods, and the truck driver told the carrier of the accident. Because Whole Foods had no representative in the area, the trooper offered, and Whole Foods agreed, to transport the truck driver to Sacred Heart Hospital for postaccident testing.[37] At this hospital, a laboratory technician conducted urine and breath testing. The breath test for alcohol was conducted at 6:35 a.m. and the urine test, for alcohol and illicit drugs, was conducted at 6:50 a.m. Results were negative for both tests. A voluntary blood sample was taken from the truck driver 12 hours after the accident. The Wisconsin State Laboratory of Hygiene toxicology laboratory reported that no drugs or alcohol was detected in the blood specimen.[38]

Motorcoach Driver. Toxicological specimens were collected during the postmortem examination of the motorcoach driver. The Wisconsin State Laboratory of Hygiene toxicology laboratory reported that no drugs or alcohol was detected in the specimen.[39]

Slope Testing

The WISDOT *Facilities Development Manual* and the 2002 AASHTO *Roadside Design Guide* indicate that a *recoverable slope* is a slope on which most motorists can generally stop their vehicles or slow them enough to return to the roadway safely. Recoverable slopes are 4:1 (4 foot horizontal to 1 foot vertical) or flatter. A *nonrecoverable (traversable) slope* is a slope on which most motorists will be unable to stop or return to the roadway easily but one that will not cause a vehicle to overturn. On nonrecoverable (traversable) slopes, vehicles can continue to the bottom of the ditch. Nonrecoverable (traversable) slopes are between 3:1 and 4:1. A *critical slope* is

[37] Title 49 CFR Part 382 requires motor carriers to conduct postaccident alcohol and drug testing. If alcohol tests are not administered within 2 hours, the motor carrier must maintain a file stating the reasons why the test was not promptly administered. The regulations also state that a motor carrier shall cease attempts to administer alcohol tests if not done within 8 hours and cease attempts to administer tests for controlled substances if specimens are not collected within 32 hours. Title 49 CFR 40.85 requires testing for marijuana metabolites, cocaine metabolites, amphetamines, opiate metabolites, and phencyclidine.

[38] The truck driver's blood specimen was screened for ethanol, marijuana, cocaine, opiates, benzodiazepines, phencyclidine, barbiturates, amphetamines, over-the-counter medications, and common prescription medications.

[39] The postmortem blood specimen from the motorcoach driver was screened for ethanol, marijuana, cocaine, opiates, benzodiazepines, phencyclidine, barbiturates, amphetamines, over-the-counter medications, and common prescription medications.

a slope on which a vehicle is likely to overturn. Critical slopes are steeper than 3:1. Slopes steeper than 3:1 should be evaluated for a roadside barrier.[40]

On October 20, 2005, Safety Board and WSP investigators collected side slope data for the accident area.[41] Measurements were taken every 20 feet beginning at milepost 85 and are shown in table 5. The side slope at the beginning of the tire furrows (140 feet from milepost 85) was a nonrecoverable (traversable) slope. However, the majority of the side slope measurements showed recoverable slopes. None of the side slopes were critical.

Table 5. Determination of slopes parallel to I-94 in the vicinity of the accident. (Shaded cells within the table rows indicate the start and end of tire furrows on the side slope.)

Distance (feet)	Side slope	Side slope category	Distance (feet)	Side slope[a]	Side slope category
0[b]	3:1	Nonrecoverable (traversable)	420	4.3:1	Recoverable
20	3.2:1	Nonrecoverable (traversable)	440	5:1	Recoverable
40	3:1	Nonrecoverable (traversable)	460	5:1	Recoverable
60	3:1	Nonrecoverable (traversable)	480	4.2:1	Recoverable
80	3:1	Nonrecoverable (traversable)	500	4:1	Recoverable
100	3.3:1	Nonrecoverable (traversable)	520	4:1	Recoverable
120	3.3:1	Nonrecoverable (traversable)	540	4:1	Recoverable
140[c]	3.2:1	Nonrecoverable (traversable)	560	3.8:1	Nonrecoverable (traversable)
160	3.6:1	Nonrecoverable (traversable)	580	4.5:1	Recoverable
180	3.3:1	Nonrecoverable (traversable)	600	4:1	Recoverable
200	3.6:1	Nonrecoverable (traversable)	620[d]	5:1	Recoverable
220	3.3:1	Nonrecoverable (traversable)	640	3.8:1	Nonrecoverable (traversable)
240	3.7:1	Nonrecoverable (traversable)	660	5.9:1	Recoverable
260	5.3:1	Recoverable	680	4.5:1	Recoverable
280	4.3:1	Recoverable	700	3.6:1	Nonrecoverable (traversable)
300	4.8:1	Recoverable	720	3.2:1	Nonrecoverable (traversable)
320	4.3:1	Recoverable	740	3.7:1	Nonrecoverable (traversable)
340	4.8:1	Recoverable	760	3.2:1	Nonrecoverable (traversable)

[40] These measurements are designed for passenger car operation and do not consider vehicles with high centers of gravity.

[41] Side slopes were taken using a Smart Level Digital Inclinometer, a device that measures percent of grade.

360	3.6:1	Nonrecoverable (traversable)	780	4:1	Recoverable
380	4:1	Recoverable	800	4.3:1	Recoverable
400	4:1	Recoverable			

[a]The slide slope is expressed as the horizontal distance for every 1 foot of vertical distance.
[b]Side slope study begins at milepost 85.
[c]Start of tire furrows on side slope.
[d]End of tire furrows on side slope.

Truck Tractor and Motorcoach Lighting Testing

Truck Tractor. The Safety Board Materials Laboratory examined the tractor's left and right headlight assemblies and its left and right taillights on December 9, 2006. Results are provided in table 6.

Table 6. Truck tractor light bulb testing results.

Bulb	Condition
Left-front headlight—low beam	Single-filament light bulb. Filament was intact, not stretched.[a]
Left-front headlight—high beam	Single-filament light bulb. Filament was intact, not stretched.
Left-front daytime running light and turn signal	Two-filament light bulb with a rounded amber-colored glass envelope. The smaller of the two filaments was lightly sagged, not stretched. The larger filament was intact, not stretched.
Left-front side marker light	Single-filament light bulb. Filament was fractured,[b] stretched, and aged.
Left-front fog light	Single-filament light bulb. Filament was fractured, not stretched, and had age etching.
Right-front headlight—low beam	Single-filament light bulb. Filament was fractured with melted and balled material at the fracture, consistent with a burnt-out condition. Not stretched but aged.
Right-front headlight—high beam	Single-filament light bulb. Filament was intact, not stretched.
Right-front daytime running light and turn signal	Two-filament light bulb with a rounded amber-colored glass envelope. Both filaments were intact; neither was stretched.
Right-front side marker light	Single-filament light bulb. Filament was fractured, and multiple locations were stretched.
Right-front fog light	Single-filament light bulb. There was fusing and arching between the coils of the filaments. Filament was fractured, and due to fusing, stretch condition could not be determined.
Left taillight	Taillight casing was intact. Two-filament light bulb. One filament was smaller in diameter than the other. The smaller filament was stretched and fractured. The larger filament showed significant aging. The larger filament was intact and not stretched.
Right taillight	Taillight casing was intact. Bulb had two filaments. One filament was smaller in diameter than the other. The smaller filament was stretched and fractured. The larger filament was not stretched but fractured.

[a]Stretching of a filament indicates that the bulb was illuminated during impact.
[b]Fracturing of a filament indicates that the bulb was not illuminated during impact.

Motorcoach. The Safety Board Materials Laboratory examined the motorcoach's headlight and interior indication panel bulbs after the accident.

Two of the four headlight bulbs survived the impact, one on each side. The light bulbs had two filaments. The filaments of the left bulb were intact and appeared to be the same size. Neither filament showed signs of stretching. The right-front bulb showed stretching to one filament.

To determine whether the bulbs were part of the headlight low-beam or high-beam assemblies, they were compared with the headlight wiring harness and sealed beam units from exemplar headlight units. Both of the dual-filament lamp units and associated electrical connectors removed from the accident motorcoach consisted of a single green wire at one connection, which provided power to the low-beam lamp filament; two white wires at the second connection, which provided power to the high-beam lamp filament; and two black wires at the third connection, which provided a vehicle ground. Each wire or pair of wires terminated at a blade-type connection within a black plastic terminal block that enclosed all three electrical connections. The low-beam connector for the accident motorcoach and the exemplar unit were configured in the same way—one terminal with a single wire and the remaining two terminals with a pair of wires. The spacing and layout of the terminals within the three-bladed electrical connectors were the same for both vehicles.

The inboard or high-beam sealed beam from the exemplar unit had a configuration different from the low-beam units. The high-beam units had a single lamp filament, and the connection used two blade-type electrical terminals, one for power and one for ground. Each of these terminals used a single wire. The wires attached to the high-beam sealed beam unit originated from the two terminal connections on the low-beam headlights and consisted of a pair of wires. Each of these paired wires provided service for both the low-beam and high-beam units.

Two clusters of lights from inside the motorcoach were also recovered. One cluster of lights was attached to a panel that had been mounted on the dash and would have signaled the driver about various motorcoach operations. For example, they would have indicated such things as the status of the stop lamps, the high-beam lights, and the turn signals, and they would have prompted the driver to check the engine. The light bulbs for "Park Brake," "→," "Back Up Lamps," and "Retarder HOT" were missing. The filaments in the "Low Fuel," "Retarder ON," "Request Stop," and "Step Out" indicator bulbs were broken. The fragments were trapped in the bases and could not be examined. The filament for the "Stop Lamps" indicator bulb was intact and showed significant stretching. The filament for the "High-Beams" indicator bulb was fractured but not stretched. The remaining indicator light bulbs, for "Hazard," "Low Air Tag Axle," "Kneel," "Clear Lights," "ABS," "In Station Lighting," "Ent Door Lock," "Door Open," "Retarder OFF," and "Retarder Applied," showed no signs of stretching. The other cluster of lights was missing the label panel.

Postaccident Visibility Study

Safety Board investigators, with the cooperation of the WSP, WISDOT, and Chippewa Trails, conducted a visibility study at the accident site between 1:45 a.m. and 4:30 a.m. on October 21, 2005, five days after the accident. The final protocol for the study included approaches by the motorcoach in the right-hand lane in both low-beam and high-beam headlight configurations, and with and without approaching traffic in the eastbound lanes of the highway.

The eastbound and westbound lanes of I-94 near the accident site were closed to traffic between midnight and 4:30 a.m., and traffic was detoured around the accident site using the adjacent highway exits. The wreckage of the Whole Foods truck-tractor semitrailer was repositioned to its approximate accident location. The exemplar motorcoach was nearly identical to the accident motorcoach. On the exemplar motorcoach, the low-beam headlight cone depth measurement was 271 feet and the high-beam headlight cone depth measurement was 479 feet.[42] Weather and astronomical conditions were similar to the conditions on the night of the accident. The exemplar motorcoach was moved slowly toward the overturned truck. (See table 7 for the findings of the visibility study.)

Table 7. October 21, 2005, visibility study findings.

Headlight beam configuration	Approaching eastbound traffic	Recognition and action	Distance (feet)
Low	None	Unknown object on shoulder	1218
Low	None	Unidentified hazard on shoulder	480
Low	None	Hazard in right lane and brake to reduce speed	329
Low	None	Hazard in right lane and emergency braking to stop	227
High	None	Hazard in right lane and brake to reduce speed	786
Low	One approaching car	Hazard in the right lane and brake to reduce speed	281
High	One approaching car	Hazard in the right lane and brake to reduce speed	604
Low	Two approaching cars	Hazard in right lane and brake to reduce speed	259
For comparison with conditions at the time of the accident, on October 21, 2005, the 1:56 a.m. weather observation at Chippewa Valley Regional Airport recorded a temperature of 35º F, winds at 3 knots, visibility unrestricted at 10 statute miles, the sky clear, and a dew point temperature of 35º F. No precipitation was reported within the previous 24 hours. At 3:45 a.m., an updated report was issued for the airport. Reported winds were calm, visibility was 1.75 miles in mist, the sky was clear, the temperature was 34º F, the dew point was 32º F, and the visibility was between 0.75 and 5 miles. Astronomical data at 2:00 a.m. indicated the moon was 59.7 degrees above the horizon at an azimuth of 115 degrees, with a 0.84 fraction of the moon illuminated.			

[42] The *cone depth measurement* is the estimated maximum forward distance to which a headlight projects its cone of illumination.

Roadway Departure Simulations

The Safety Board simulated the departure of the accident truck from the roadway and its return to the roadway.[43] For a 4:1 side slope and coefficient of friction of 0.60 on the grassy area to the right of the shoulder, the maximum speed at which the vehicle returned to the roadway without rolling over was 60 mph.

The estimated speed of the truck in the Osseo accident was 63 to 69 mph, and additional simulations were performed to determine whether an electronic stability control (ESC) system could have increased the speed at which the vehicle could have safely returned to the roadway without rolling over. A Bendix ESC controller hardware was interfaced to the TruckSim software model so that the combined simulation represented the accident truck equipped with an ESC system.[44] The simulations indicated that the addition of an ESC system did not increase the accident truck's maximum safe return speed to above 60 mph.

Other Information

Technologies That Detect Fatigue and Countermeasures to Drowsy Driving

Analysis of 2005 Fatality Analysis Reporting System (FARS) data indicates that 1.7 percent of drivers of large trucks involved in fatal accidents were coded as drowsy, asleep, or fatigued.[45] Thirteen percent of the drivers in the FMCSA's large truck crash causation study were coded with driver fatigue as an associated factor in the accident.[46] A 1990 Safety Board study of 182 fatal-to-the-truck driver accidents found driver fatigue to be the probable cause in 31 percent of the accidents; fatigue was the most frequently cited probable cause.[47]

As described in a 1999 Safety Board safety report, fatigue affects many aspects related to driving safety.[48] Traditionally, fatigue has been viewed as a simple condition related to the amount of time spent working on a given task.[49] Scientific

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[43] The simulation was conducted using the TruckSim simulation package from Mechanical Simulation Corporation.

[44] ESC systems for trucks employ proprietary control logic, the details of which are kept as trade secrets by the manufacturers and, therefore, could not be incorporated into the TruckSim simulation software.

[45] U.S. Department of Transportation, Federal Motor Carrier Safety Administration, *Large Truck Crash Facts 2005*, FMCSA-RI-07-046 (Washington, DC: FMCSA, February 2007).

[46] U.S. Department of Transportation, Federal Motor Carrier Safety Administration, *Large Truck Crash Causation Study: Analysis Brief*, FMCSA-RRA-07-017 (Washington, DC: FMCSA, July 2007).

[47] National Transportation Safety Board, *Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes*, Safety Study NTSB/SS-90/01 (Washington, DC: NTSB, 1990).

[48] National Transportation Safety Board, *Evaluation of the U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue*, Safety Report NTSB/SR-99/01 (Washington, DC: NTSB, 1999).

[49] N. McDonald, *Fatigue, Safety and the Truck Driver* (London and Philadelphia: Taylor & Francis, 1984) 104-115.

research, however, has shown that fatigue concerns much more than just the time on a task.[50] Researchers have studied factors that affect fatigue, such as duration and quality of sleep,[51] shiftwork and work schedules,[52] circadian rhythms,[53] and time of day.[54] Others have examined the influence of drugs and alcohol on fatigue.[55] Alcohol, which has sedating effects, may speed up the onset of sleep but makes it harder to stay asleep, negatively affecting the quality of sleep. As the alcohol is metabolized, sleep is fragmented, and people wake up more frequently.[56] Sleep disorders and the characteristics of sleep patterns of subjects of different ages have also been studied.[57] Cumulative sleep loss and circadian disruption can lead to a physiological state characterized by impaired performance and diminished alertness.[58] Fatigue can impair information processing and reaction time, increasing the probability of errors and ultimately leading to transportation accidents.[59] Sleep

50 M.H. Kryger, T. Roth, and W.C. Dement, eds., *Principles and Practices of Sleep Medicine*, 2nd ed. (Philadelphia: W.B. Saunders Company, 1994).

51 (a) L.C. Johnson and P. Naitoh, *The Operational Consequences of Sleep Deprivation and Sleep Deficit*, AGARD-AG-193 (London: NATO Technical Editing and Reproduction, 1974). (b) M.R. Rosekind, P.H. Gander, L.J. Connel, E.L. Co, *Crew Factors in Flight Operations. X Alertness Management in Flight Operations,* NASA/FAA Technical Memorandum DOT/FAA/RD-93/18 (Washington, DC: National Aeronautics and Space Administration, 1994). (c) National Transportation Safety Board, *Factors That Affect Fatigue in Heavy Truck Accidents*, Safety Study NTSB/SS-95/01 and NTSB/SS-95/02 (Washington, DC: NTSB, 1995).

52 (a) S. Folkard, T.H. Monk, and M.C. Lobban, "Towards a Predictive Test of Adjustment to Shiftwork," *Ergonomics* Vol. 21 (1979): 785-799. (b) G.R. Thomas, T.G. Raslear, G.I. Kuehn, *The Effects of Work Schedules on Train Handling Performance and Sleep of Locomotive Engineers: A Simulator Study*, DOT/FRA/ORD-97-09 (Washington, DC: Federal Railroad Administration, 1997).

53 M.H. Kryger, T. Roth, M. Carskadon, "Circadian Rhythms in Humans: An Overview." In M.H. Kryger, T. Roth, and W.C. Dement, eds. *Principles and Practice of Sleep Medicine*, 2nd ed. (Philadelphia: W.B. Saunders Company, 1994) 301-308.

54 C.D. Wylie, T. Shultz, J.C. Miller, and others, *Commercial Motor Vehicle Driver Fatigue and Alertness Study: Project Report*, FHWA-MC-97-002 (Washington, DC: FHWA, 1996).

55 T. Roehrs, D. Beare, F. Zorick, and T. Roth, "Sleepiness and Ethanol Effects on Simulated Driving," *Alcoholism: Clinical and Experimental Research*, Vol. 18(1) (1994): 154-158.

56 National Highway Traffic Safety Administration, "Wake Up and Get Some Sleep" brochure. See <http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/human/drows_driving/wbroch/wbroch_lg/wbroch_lg.html>, accessed June 19, 2008.

57 (a) M.S. Alfrich, "Cardinal Manifestations of Sleep Disorders." In M.H. Kryger, T. Roth, and W.C. Dement, eds. *Principles and Practice of Sleep Medicine*, 2nd ed. (Philadelphia: W.B. Saunders Company, 1994) 413-425. (b) D.L. Bliwise, "Normal Aging." In *Principles and Practice of Sleep Medicine*, 26-39.

58 M.R. Rosekind, R.C. Graeber, D.F. Dinges, and others, *Crew Factors in Flight Operations. IX: Effects of Planned Cockpit Rest on Crew Performance and Alertness in Long-Haul Operations,* National Aeronautics and Space Administration Technical Memorandum 108839, DOT/FAA/92/94 (Washington, DC: NASA, 1993).

59 (a) D.F. Dinges, "The Nature of Sleepiness: Causes, Context, and Consequences." In: A. Stunkard and A. Baum, eds., *Perspectives in Behavioral Medicine: Eating, Sleeping, and Sex* (Hillsdale, NJ: Lawrence Erlbaum, 1989) 147-179. (b) D.F. Dinges, "Probing the Limits of Functional Capability: The Effects of Sleep Loss of Short-Duration Tasks." In: R.I. Broughton and R. Oglivie, eds. *Sleep, Arousal, and Performance* (Boston: Birhauser-Boston, 1992) 176-188.

deprivation has also been shown to affect specific aspects of driving performance, such as lane excursion, lateral placement, and speed.[60,61]

A variety of technological countermeasures can potentially detect fatigue and prevent fatigue-related accidents. These technologies are frequently classified as

- *Driver-based systems*, which typically monitor aspects of the driver's condition, such as eyelid closure, eye blinks, or brain activity,
- *Vehicle-based systems,* which are designed to monitor aspects of vehicle movement, such as lane departures or steering wheel movement, and
- *Environmental-based countermeasures*, which include such items as rumble strips and adequate rest areas.[62]

Driver-Based Systems. One of the most accurate means of quantifying fatigue is by using electroencephalograph (EEG) measures. Brain waves, and thereby, stages of alertness or sleep, are monitored through small electrodes attached to the scalp. Although this measurement technique is accurate, it is not practical for in-vehicle use.[63]

Wrist-worn devices have also been developed that monitor a driver's sleep/wake history and then, through use of an algorithm, provide feedback to the driver regarding sleep needs and performance readiness. This system can provide accurate information on the amount of sleep time obtained by the user. One obstacle to using this tool is that the device must be worn during the driver's off-duty time for accurate data collection.[64]

Other, less intrusive, means of measurement include monitoring eye or head movements. A study sponsored by NHTSA and the FHWA examined the validity of six drowsy-driving technologies (video-based scoring of eye closure by trained observers, two EEG algorithms, a head tracker device, and two wearable eye-blink monitors).[65] One measure, PERCLOS, determines the percentage of eyelid closure over the pupil, over time, correlated with attention lapses as measured by a psychomotor vigilance test. NHTSA and the FMCSA conducted a field operational test to gain a better understanding of the safety benefits associated

[60] R.D. Peters, E. Wagner, E. Alicandri, J.E. Fox, M.L. Thomas, D.R. Thorne, H.C. Sing, and S.M. Balwinski, "Effects of Partial Sleep Deprivation on Driving Performance," *Public Roads* Vol. 62. No. 4 (January/February 1999).

[61] Safety Recommendations I-89-2, H-95-5, and H-99-4a concerning fatigue are discussed in this report's "Analysis."

[62] Transportation Research Board, *Sleep Deprivation Countermeasures for Motorist Safety,* NCHRP Synthesis 287 (2000).

[63] L. Hartley, T. Horberry, N. Mabbott, and G. Krueger, *Review of Fatigue Detection and Prediction Technologies*, National Road Transport Commission (2000).

[64] Per Dr. Gregory Belenky, Washington State University, speaking to Safety Board staff, August 15, 2008.

[65] D.F. Dinges, M.M. Mallis, G. Maislin, and J.W. Powell IV, *Final Report: Evaluation of Techniques for Ocular Measurement as an Index of Fatigue and as the Basis for Alertness Management*, DOT HS 808 762 (Washington, DC: NHTSA, 1998).

with the PERCLOS system. Data were collected on 102 commercial truck drivers and 34 single-unit trucks.[66] A final report is expected later this year.

Vehicle-Based Systems. Lane departure warning systems (LDWS) monitor the road and the vehicle's position within the lane. Such systems warn the driver if the vehicle drifts from the lane. Under certain conditions, such as when a turn signal is activated or when the vehicle is traveling at low speeds (at or below 35 mph), the warning signal is blocked.[67]

The FMCSA sponsored a field operational test of the SafeTRAC LDWS to determine its safety benefits.[68] On-board driving data were collected for 22 trucks and 31 drivers over a 12-month period (March 2004 to March 2005). Analysis indicated that the use of the LDWS reduced driving conflicts associated with single-vehicle road-departure and rollover crashes.[69] Only a small number of drivers responded to a user survey, which limited researchers' ability to make valid generalizations concerning these results; nevertheless, the majority of those drivers who did respond said that the LDWS improved their lane-keeping ability. Some felt the system helped them to drive in a straighter path and maintain alertness, but others indicated that they found the alert tones annoying and startling, and that it was sometimes difficult to distinguish the alert tones from other systems in the truck.

The USDOT sponsored a field test of another road departure crash avoidance system.[70] This system comprises a lane drift warning system and a curve speed warning system. The lane drift warning system uses radar to identify objects in the roadway and a lane tracking/drift detection camera to detect the vehicle's position in the lane. The curve speed processor uses GPS to estimate the geometry of the upcoming roadway. A combination of visual, auditory, and/or tactile signals is provided to the driver. This test was completed by 78 drivers operating 11 passenger vehicles (Nissan Altima platform) equipped with the road-departure crash avoidance system over 4-week periods (a 1-week baseline period with the system activated but unavailable to the driver, followed by 3 weeks with the system activated and available to the driver). Preliminary findings showed a reduction in lane departures and near-departures; the majority of system users believed that the lane drift warning system made them more aware of their vehicle's location

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[66] P. Rau, *Drowsy Driver Detection and Warning System for Commercial Vehicle Drivers: Field Operational Test Design, Data Analyses, and Progress*, Paper Number 05-0192 (2005).

[67] Federal Motor Carrier Safety Administration, *Lane Departure Warning Systems and Deployment*, <www.fmcsa.dot.gov/facts-research/research-technology/conference/rt-forum-2006-ppt3.htm>.

[68] J. Orban, J. Hadden, G. Stark, and V. Brown, *Evaluation of the Mack Intelligent Vehicle Initiative Field Operational Test*, FMCSA-06-016 (September 2006).

[69] A "driving conflict" was considered a potential crash situation.

[70] The field operational test was conducted through a partnership of the FHWA, the University of Michigan Transportation Research Institute (UMTRI), AssistWare Technology Corporation, and Visteon Corporation.

within the roadway, that the curve speed warning system provided information about upcoming curves, and that both systems would improve driving safety.[71]

LDWSs can benefit driving performance no matter the cause of the driver's impairment. That is, an LDWS warns the driver that the vehicle is drifting from its lane regardless of whether the driver is impaired by fatigue, driver distraction, poor driving, or other conditions. LDWSs can help prevent single-vehicle roadway departures, lane change/merge incidents, and head-on crashes. Increasing the use of turn signals and reinforcing driver awareness are potential benefits of LDWS.

Another system for detecting drowsy driving is to monitor steering positions. The Center for Intelligent Systems Research (CISR) at George Washington University has developed a system that observes car drivers' steering angle patterns and classifies them into drowsy and nondrowsy driving intervals.[72] Simulator studies have shown the classification system to have high accuracy.[73] CISR recently developed a system to detect drowsy driving in commercial drivers. The system, based on steering input, correctly predicted drowsy driving intervals with 85-percent accuracy.[74]

Environmental-Based Countermeasures. Changes can also be made to the environment to prevent drowsy driving crashes. Two potential changes to the environment are providing rumble strips and ensuring that adequate rest areas are available to tired truckers. Excess noise, hazards to bicyclists, and maintenance issues have been raised as concerns with respect to rumble strips.

The Pennsylvania Turnpike Commission conducted a study of narrow and recessed rumble strip patterns that would produce enough sound and vibration to be perceptible in a truck cab and yet not too severe for cars or motorcycles.[75] The rumble strips for the study were 16 inches long (perpendicular in the direction of travel) and 7 inches wide (length in the direction of travel). The rumble strips were spaced 5 inches apart with a depression depth of 0.5 inch. The selected design produced a sound audible of 89 decibels in truck cabs. Single-vehicle drift-off-the-road accidents declined by 60 percent after the installation of the rumble strips over 348 miles of roadway (from 3.81 to 1.54 accidents per 100 million vehicle

[71] L. Emery, G. Srinivasan, D.A. Bezzina, D.J. LeBlanc, J.R. Sayer, S. Bogard, and D. Pomerleau, Status report on USDOT project, "An intelligent vehicle initiative road-departure crash warning field operational test," ESV: 19th International Technical Conference on the Enhanced Safety of Vehicles (2005).

[72] See <www.cisr.gwu.edu/research/drowsy_details.html>, accessed June 19, 2008.

[73] R. Sayed, A. Eskandarian, and M. Oskard, *Driver Drowsiness Detection Using Artificial Neural Networks* (Washington, DC: Transportation Research Board, 2001) abstract.

[74] A. Eskandarian, R. Sayed, P. Delaigue, J. Blum, and A. Mortazavi, *Advanced Driver Fatigue Research* (Washington, DC: FMCSA, 2007).

[75] J.J. Hickey, *Shoulder Rumble Strip Effectiveness: Drift-Off-Road Accident Reductions on the Pennsylvania Turnpike*, presented at the 76th Annual Meeting of the Transportation Research Board, published in Transportation Research Record 1573 (Washington, DC: TRB, January 1997).

miles traveled). The rumble strips are estimated to have prevented 100 accidents per year on the Pennsylvania Turnpike.

Other States have also examined the effectiveness of rumble strips. Michigan found a 40-percent reduction in drift-off-the-road accidents when milled rumble strips were present, a reduction in accidents less significant than the one experienced in Pennsylvania and, according to researchers, perhaps attributable to differences in the locations of the rumble strips. In Michigan, the rumble strips were installed at 300-millimeter (12-inch) and 600-millmeter (24-inch) offsets from the inside edges of the shoulders, whereas in Pennsylvania the rumblestrips were placed at 100-millmeter (4-inch) offsets, suggesting to researchers that the closer the rumble strip is to the edge line, the more effective it may be in reducing crashes.[76] Montana found rumble strips to be most effective in reducing the crash rate and the severity of run-off-the-road and rollover crashes on interstate highways.[77] Comparisons before and after rumble strip installation showed a 24-percent reduction in the crash rate and a 23.5-percent reduction in the severity of run-off-the-road crashes.

Rest areas are needed to provide a safe place for drivers to rest.[78] In 2002, the FHWA submitted a report to Congress on the adequacy of parking facilities.[79] In the report, the FHWA acknowledged that several factors affect the demand for parking facilities, including just-in-time deliveries, area location, and hours-of-service (HOS) regulations.[80] The FHWA determined that adequate numbers of parking areas were available for trucks and buses nationwide; however, certain States experienced a shortage of parking areas. The FHWA recommended that the States with shortages of parking areas expand or improve public rest areas and commercial truck stops and travel plazas.[81]

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[76] D.A. Morena, “Rumbling Towards Safety” *Public Roads* Vol. 67, No. 2 (2003).

[77] R.R. Marvin and D.J. Clark, *An Evaluation of Shoulder Rumble Strips in Montana*, FHWA/MT-03-008/8157 (2003).

[78] Safety Recommendations H-00-17 through -24 concerning rest areas are discussed in this report’s “Analysis.”

[79] Federal Highway Administration, *Report to Congress Study of Adequacy of Parking Facilities* (June 2002).

[80] The demand model used to evaluate the parking facility adequacy used the HOS regulations in place at the time, which limited a driver to 10 hours of driving or 15 hours of on-duty time following 8 hours off-duty time. The effect of the new HOS regulations, which became effective October 1, 2005, has not been assessed.

[81] According to the 2002 FHWA report to Congress, the States with sufficient numbers of commercial spaces are Alabama, Arkansas, Louisiana, Maryland, New York, Rhode Island, Virginia, and West Virginia. States with a surplus of spaces are Arizona, Florida, Georgia, Iowa, Kansas, Maine, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, North Dakota, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Utah, Vermont, Wisconsin, and Wyoming. States with a shortage of spaces are California, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Kentucky, Massachusetts, Ohio, Texas, and Washington. The number of parking spaces was not determined for Alaska.

As part of the report on the adequacy of parking facilities, the FHWA conducted a driver survey concerning parking facilities.[82] Results indicated that drivers preferred public rest areas for short stops (2 hours or less), but for longer stops, they preferred a commercial truck stop or travel plaza. Many respondents indicated that they had difficulty finding available parking at rest areas and truck stops.

The FHWA administers a parking facilities program that provides funding to States, metropolitan planning organizations, and local governments to address the shortage of long-term parking facilities. Funds are available to promote the real-time dissemination of publicly or privately provided CMV parking availability on the National Highway System (NHS) using intelligent transportation systems (ITS) and other means; to open nontraditional facilities to CMV parking, including inspection and weigh stations and park-and-ride facilities; to make capital improvements to public CMV parking facilities currently closed on a seasonal basis that would allow the facilities to remain open year-round; to construct turnouts along the NHS to facilitate CMV access to parking facilities and/or improve the geometric design of interchanges to improve access to commercial vehicle parking facilities; to construct CMV parking facilities adjacent to commercial truck stops and travel plazas; and to construct rest areas that include parking for CMVs.[83] The FHWA has recently dedicated $11 million to use ITS technologies to provide truck drivers with real-time information on available parking on Interstate 95 and Interstate 5.[84] The technology will also explore ways to allow truck drivers to reserve parking spaces in advance.

Collision Warning Systems

Collision warning systems (CWS) are typically radar-based systems that track other vehicles and stationary objects in the equipped vehicle's forward path, with the purpose of preventing rear-end collisions.[85] Most systems do not take the responsibility for braking from the driver. However, some CWSs are equipped with automatic braking systems that will actively brake the vehicle if the driver does not take action once a warning is issued. Systems currently on the market sound an initial warning at a distance of 350 feet from a detected obstacle. For a stationary or stopped obstacle, the highest warning level is given at 220 feet of the object.[86]

[82] K.J. Chen, K.K. Pecheux, J. Farbry, Jr., and S.A. Fleger, *Commercial Vehicle Driver Survey Assessment of Parking Needs and Preferences*, FHWA-RD-01-160 (2002).

[83] *Federal Register*, November 16, 2007, Volume 72, Number 221, Federal Highway Administration, *Announcement of Application Procedure and Deadlines for the Truck Parking Initiative*.

[84] July 9, 2008, USDOT press release. See <http://www.fhwa.dot.gov/pressroom/fhwa0813.htm>, accessed July 9, 2008.

[85] Safety Recommendations H-95-44 and H-01-6 and -7 concerning CWSs are discussed in this report's "Analysis."

[86] The highest warning level of the Eaton Vorad CWS provides the driver with both visual and auditory warnings.

According to FARS data, in 2006, there were 2,339 crashes including a front-to-rear collision; the crashes involved 47 buses, 1,008 trucks, and 4,436 passenger cars and other vehicle types. Thirty-seven percent of the trucks involved in these accidents struck another vehicle, and 19 percent of the buses struck another vehicle. (See figure 13.)

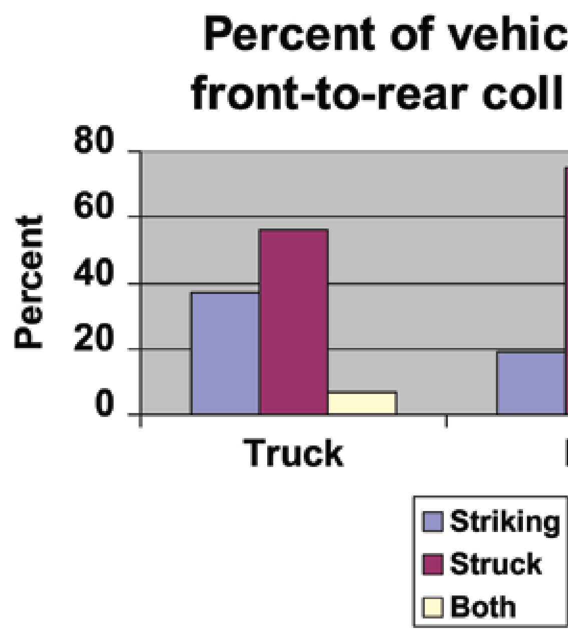

Figure 13. 2006 FARS data on front-to-rear collisions.

An FMCSA analysis using a combined dataset of 1994–1999 "Trucks Involved in Fatal Accidents" and General Estimates System data showed that rear-end crashes accounted for 18 percent of all large trucks involved in crashes (70,000 rear-end crashes of 380,000 large truck crashes).[87] In fatal accidents, large trucks were more often struck, but in no-injury or possible-injury accidents, large trucks were more likely to be the striking vehicle. In 18 percent of rear-end crashes in which the truck was the striking vehicle, three or more vehicles were involved in the crash. In fatal rear-end crashes, 46 percent of the accidents in which a truck was the striking vehicle involved three or more vehicles, compared to 16 percent of the accidents in which the truck was struck. The FMCSA attributed this finding to the larger mass of a truck as compared to most passenger vehicles. An 80,000-pound loaded tractor-trailer will not be stopped or slowed significantly by a typical 4,000-pound passenger vehicle.

Although CWSs on large buses have not been studied, CWS technology has been evaluated on large trucks. As part of the USDOT's Intelligent Vehicle

[87] R. Craft, *Rear-End Large Truck Crashes*. See <www.fmcsa.dot.gov/facts-research/brief/rear.pdf>, accessed January 21, 2008.

Initiative, the FHWA sponsored a field operational test involving large trucks to evaluate the viability of rear-end CWS, as well as adaptive cruise control (ACC) and an electronically controlled brake system (ECBS).[88,89] One hundred new Volvo tractors were operated over a 3-year period beginning in 2001; 50 were equipped with a commercially available Eaton VORAD EVT 300 CWS and another 50 were equipped with the CWS, as well as an ACC system that used conventional cruise control, Volvo disc brakes, and an ECBS.[90,91]

The field operational test showed a 28-percent reduction in rear-end crashes as a result of the CWS, ACC, and brake systems bundled together and a 21-percent benefit from the CWS alone. Deployment of the CWS system to the 1.8 million-vehicle truck fleet was projected to prevent 4,700 rear-end crashes, 2,500 injuries, and 96 fatalities each year. The field test included a driver survey to evaluate driver acceptance. Most drivers said they believed the technologies made them drive safer, and over 80 percent indicated that they would prefer to drive a truck equipped with a CWS. The major complaint about the CWS was the incidence of false alarms.

CWSs are limited in some conditions, and their detection range may be reduced. For example, lead vehicles making sharp turns may fall out of the detection area of the CWS. A CWS may give false alarms when its vehicle is traveling on roads in undulating terrain.

In October 2007, H.R. 3820 was introduced in the Ways and Means Committee of the U.S. Congress to provide a tax credit for commercial vehicles equipped with a "qualified commercial vehicle advanced safety system." Brake stroke monitoring systems, LDWSs, CWSs, and vehicle stability systems are included in this bill. No additional action has been taken on this measure.

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[88] The Intelligent Vehicle Initiative was authorized in the 1998 Transportation Equity Act for the 21st Century (TEA-21).

[89] U.S. Department of Transportation, *Intelligent Vehicle Initiative Final Report*, FHWA-JPO-05-057 (Washington, DC: USDOT, 2005).

[90] The Eaton Vorad EVT 300 CWS uses forward-looking radar to constantly monitor vehicles ahead of the host vehicle. The ACC uses the CWS and conventional cruise control. If the CWS radar detects a vehicle ahead of and in the same lane as the host vehicle, the ACC will maintain a preset minimum following interval between the lead vehicle and the host vehicle. If there is no vehicle in the same lane as the host vehicle and no target within range of the radar, the system maintains a speed set by the operator. ECBS is a computer-based system that functions electronically. The system provides shorter stopping distances due to faster brake engagement/disengagement, trailer braking system compatibility and adaptive braking pressure between tractor and trailer, lining wear control and warning, and antilock braking functions.

[91] (a) Volvo Trucks North America, Inc., *Volvo Trucks Field Operational Evaluation of Advanced Safety Systems for Heavy Truck Tractors*, prepared for USDOT/FHWA, Cooperative Agreement No. DTFH61-99-X-00102 (2005). (b) Battelle, *Final Report Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version 1.3* (2007), prepared for USDOT/FHWA, Cooperative Agreement DTFH61-96-C-00077, task order 7721, <www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14352_files>, accessed January 22, 2008. (c) M.J. Lehmer, V. Brown, R. Carnell, A. Christianen, N. McMillan, J. Orban, G. Stark, R. Miller, and N.A. Rini, *Volvo Trucks Field Operational Test: Evaluation of Advanced Safety Systems for Heavy Trucks*, <http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/esv/esv20/07-0212-W.pdf>, accessed July 14, 2008.

Analysis

This analysis begins with a discussion of the factors and conditions the Safety Board has excluded as neither causing nor contributing to the Osseo, Wisconsin, accident. Then, the two individual events that comprise the full accident are separately analyzed. The analysis of the first event, the rollover of the truck-tractor semitrailer, focuses on operator fatigue and possible countermeasures. The analysis of the second event, the collision of the motorcoach with the truck-tractor semitrailer, addresses the vehicle lighting, the vision of the motorcoach driver, the motorcoach's braking capability, and CWSs.

Exclusions

At the time of the Osseo accident, skies were clear and no rain was reported. The pavement was dry. Therefore, the Safety Board concludes that the weather did not cause or contribute to the accident.

Postaccident mechanical inspection of the truck-tractor semitrailer unit indicated that the suspension system, steering system, and tires were functional and that the tractor was solidly connected to the trailer. The truck-tractor semitrailer's brakes were in adjustment and in good condition. Postaccident inspection of the motorcoach showed that, although portions of the steering and suspension system were damaged during the impact, no abnormalities were present, and the systems were most likely working properly before the crash. The air pressure measurements of the motorcoach's tires were within specifications. The Safety Board concludes that the mechanical condition of the truck-tractor semitrailer did not contribute to its departure from the roadway and subsequent rollover or to its being struck by the motorcoach; and the condition of the motorcoach's steering, suspension, and tires did not contribute to its impact with the truck-tractor semitrailer.

Postaccident toxicological tests for the motorcoach driver were negative for alcohol and drugs. The Safety Board concludes that the motorcoach driver was not impaired by alcohol or drugs at the time of the accident.

The emergency response occurred in a rural area over multiple jurisdictions, requiring the coordination of three county law enforcement communication centers. Emergency response vehicles arrived at the scene 9 minutes after the communication centers were notified. Given that the accident area was located some distance from many of the available medical facilities, the injured motorcoach passengers and the truck driver were triaged and treated on the scene and appropriately transported to area hospitals within 2 hours. Therefore, the Safety Board concludes that the emergency response was timely and adequate.

Rollover of Truck-Tractor Semitrailer

The truck driver possessed a suspended Indiana class A CDL with no restrictions or endorsements. The truck driver's license was under an administrative suspension for failure to pay a fine for a noncommercial vehicle speeding ticket. The truck driver possessed a valid medical certificate. He received 280 hours of co-driving training from Whole Foods. Therefore, the Safety Board concludes that although the truck driver's CDL had been administratively suspended for failure to pay a fine, he had passed the licensing exam and had received an additional 280 hours of training by the motor carrier, indicating that he had the abilities needed to drive the truck-tractor semitrailer.

Breath and urine testing of the truck driver took place approximately 4.5 and 5 hours after the accident, respectively. A voluntary blood specimen was taken from the truck driver 12 hours after the accident. Test results from all specimens were negative for alcohol and the drugs for which they were tested. The negative results from the urine sample taken about 5 hours after the accident indicate that illicit drugs were not a factor in this accident. However, alcohol is metabolized too quickly for the negative findings to definitively exclude impairment due to alcohol use.[92] Nevertheless, the WSP trooper who had custody of the truck driver following the accident said that the driver exhibited no signs of intoxication. No one on the scene recorded any evidence in the truck driver's behavior or manner that he was intoxicated at the time of the accident, and there is no evidence of the driver's drinking after beginning his sleep period in the previous morning. The Safety Board therefore concludes that based on urine test results, the truck driver was not impaired by illicit drugs at the time of the accident; however, although there is no evidence that alcohol was a factor in the overturn of the truck-tractor semitrailer, specimens were collected from the truck driver too late to definitively exclude impairment due to alcohol use.

Truck Driver Fatigue

The accident sequence began when the truck left the roadway. In a postaccident interview with the WSP, the truck driver said he had been pulling over to urinate, but he also said he was traveling about 66 mph. According to the Garmin GPS on the truck, the truck was traveling between 66 and 70 mph for the last 5.2 miles preceding the accident, making it unlikely that the driver intended to stop the truck. The GPS data also indicated that the truck's precrash heading was 306 degrees and that, during the last 0.1 mile, the vehicle heading changed from 305 degrees to 310 degrees to 212 degrees. These headings correlate with the known circumstances of the accident, specifically with the departure from the right side of the roadway (310-degree heading) and a counter-clockwise vehicle rotation, which would have been toward a heading of 212 degrees. The truck's shallow

[92] Based on data in R.C. Baselt, *Disposition of Toxic Drugs and Chemicals in Man*, 5th ed. (Foster City, CA: Chemical Toxicology Institute, 2000).

departure angle is consistent with a fatigue-related accident.[93] Further, drivers who shared the road with the Whole Foods truck on the night of the accident stated that the driver had not been consistently keeping the vehicle within his lane. Based on the foregoing, the Safety Board concludes that the evidence, including an average vehicle speed of between 66 and 70 mph, the shallow angle of the truck-tractor semitrailer's departure, and witness reports of the vehicle's weaving on the road, suggests that the truck driver allowed the vehicle to drift from the roadway, indicating that the driver was operating while fatigued.

The reconstruction of the truck driver's activities revealed that in the 2 days before the accident, his schedule provided him reasonable opportunity to sleep, but on the basis of his self-reported activities, he obtained (at most) 12.5 hours of sleep in this period. He reported that he slept on October 14 for about 7.5 hours (from 9:00 a.m. to 4:30 p.m.). This opportunity to sleep occurred in Minnesota, before he returned home to Indiana, and took place in the truck's sleeper berth. The driver's second sleep opportunity period would have been at home from about 6:00 a.m.[94] to 10:57 a.m. (5 hours) on October 15, the day before the accident. Other than the driver's self-reported information, the Safety Board has no corroboration for whether the driver actually slept during these two periods. The driver had the opportunity to obtain more sleep in these 2 days because he was off duty for about 20 hours.

On average, people need about 8 hours of sleep per night. Sleep deprivation, which is cumulative over time, can make a person susceptible to fatigue. Circadian desynchronization, that is, being awake when one is typically asleep or being awake during the early morning hours when the body is inclined to sleep, can also lead to sleepiness and fatigue. The accident occurred at 1:58 a.m., a time at which the body is predisposed to sleep.

The truck driver spent the later hours of Friday, October 14, and the early morning hours of Saturday, October 15, socializing at a restaurant and bar, and he consumed alcohol during that time. Alcohol has a sedating effect, meaning that the onset of sleep may occur quickly after an individual has consumed it; however, alcohol is also disruptive to sleep, causing individuals to wake up frequently during the second half of the sleep period. Thus, alcohol consumption reduces the quality of sleep and may lead to daytime fatigue and sleepiness.[95]

The Safety Board concludes that the truck driver was asleep at the time of the accident because of the reduced quantity of his sleep; the reduced quality of his sleep due to alcohol consumption the previous night; and the circadian desynchronization he experienced due to his operating the truck in the early morning hours, when the body is predisposed to sleep.

[93] Safety Study NTSB/SS-95/01.

[94] The driver told police that he had returned home at 2:00 a.m.; the WSP found that he had not returned to his home until 6:00 a.m.

[95] (a) National Institute on Alcohol Abuse and Alcoholism, *Alcohol and Sleep*, Alcohol Alert No. 41, 1998. (b) National Sleep Foundation. (c) NHTSA *Sleep* brochure.

The driver had been driving this route for about 3 weeks. It was a regular run in which the driver picked up a load at the Whole Foods Midwest distribution center in Munster, Indiana, and brought it to the St. Paul, Minnesota, area. Between runs, the driver was off duty. Prior to the accident trip, the driver had been off duty for 20 hours, in which he could have slept if he had chosen. According to the driver's own report of his activities and his cellular phone records, he slept during the off-duty time preceding his scheduled run for 5 hours, at most. Therefore, the Safety Board concludes that the Midwest distribution center of Whole Foods provided an adequate off-duty period for the Osseo truck driver to obtain sufficient sleep, but he did not take full advantage of this opportunity.

Fatigue Technologies

Before the truck left the roadway, other drivers observed the truck driver having difficulty maintaining lane alignment and repeatedly drifting out of his lane. LDWSs monitor the location of the vehicle within the lane and alert the driver when the vehicle drifts from the lane. Research results have shown that LDWSs decrease lane departures, and system users have reported that LDWSs help them to maintain their vehicles' lane positions.[96] The FMCSA has developed voluntary standards for LDWSs that include standards for functional, data, hardware and software, driver-vehicle interface, and maintenance and support requirements.[97]

Other systems that monitor the vehicle, such as steering position monitors, as well as systems that monitor driver behavior, have also been developed to detect fatigue. One of the most promising driver-monitoring systems is PERCLOS, which measures the rate of eyelid closure. NHTSA is conducting a field operational test to evaluate the effectiveness of PERCLOS in assessing driver fatigue.

The Safety Board recently completed investigations of two other accidents that resulted because of driver fatigue. In the Lake Butler, Florida, accident, a tractor-trailer collided with a Pontiac Bonneville and a school bus, killing all seven occupants of the passenger car and injuring the nine bus passengers and bus driver. This accident occurred on January 25, 2006, at 3:25 p.m. Reconstruction of the truck driver's work/rest history showed the truck's Qualcomm[98] signal was lost at 8:23 p.m. on January 23 and resumed about 9 hours later, the next morning, January 24, about 34 hours before the accident. This was the last opportunity the driver had for an extended sleep period before the accident. With the exceptions of a 2-hour sleep period beginning around 1:00 a.m. on January 25 and 1 to 2 hours of rest a few hours later, about 7:00 a.m., the truck driver was awake for about 30

[96] (a) *Evaluation of the Mack Intelligent Vehicle Initiative Field Operational Test*, FMCSA-06-016. (b) Status report on USDOT project, "An intelligent vehicle initiative road-departure crash warning field operational test."

[97] Federal Motor Carrier Safety Administration, *Concept of Operations and Voluntary Operational Requirements for Lane Departure Warning Systems (LDWS) On-Board Commercial Motor Vehicles*, July 2005.

[98] The Qualcomm Qtracs system uses a transmitter/receiver that allows objects to be continually tracked through global positioning satellites. The system identifies the location of each truck every hour, as well as the corresponding time and date and whether the truck engine is running.

hours during this 34-hour period. The Safety Board determined that the probable cause of the accident was the failure of the truck driver to maintain alertness due to fatigue from obtaining inadequate rest. Contributing to the accident was the failure of the motor carrier to exercise proper oversight of the driver's hours of service. (More information on the Lake Butler accident can be found in appendix B.)

On October 9, 2004, a 1988 47-passenger motorcoach transporting 29 passengers to a casino in Tunica, Mississippi, was traveling southbound on Interstate Highway 55 near Turrell, Arkansas. At exit 23A, the motorcoach veered to the right and entered a grassy area between the exit and entrance ramps. The motorcoach overturned onto its left side. The accident resulted in 15 fatalities and 15 injuries. The Turrell motorcoach driver had been awake approximately 19 hours at the time of the accident. He had been on duty for about 9 hours and had been driving for the last 8 hours. He had made two brief stops at rest areas to let passengers use the restrooms. Although the driver had obtained a full night's sleep the night preceding the accident and had taken a nap during the day, the scheduling of the trip deprived him of his customary nighttime sleep period. The Safety Board determined that the motorcoach driver's fatigued condition caused him to allow his vehicle to drift off the left side of the roadway, contacting the rumble strips. He reacted to the warning provided by the rumble strips by oversteering the motorcoach to the right and then off the roadway. (More information on the Turrell accident can be found in appendix C.)

Fatigue technologies are designed to monitor driver behaviors such as eyelid closure or head position, or vehicle actions such as steering wheel input or lane drift. The USDOT has been examining fatigue detection systems, and the research has shown promising results regarding the effectiveness of fatigue detection systems. Had fatigue monitoring devices been available in the vehicles in these three accidents (Osseo, Lake Butler, and Turrell), it is possible that the accidents could have been prevented. Such on-board devices could have signaled the drivers that their alertness was diminishing, both helping to increase their alertness in the short term and prompting them to seek opportunities to rest safely. Specifically, the Safety Board concludes that had the Osseo truck-tractor semitrailer been equipped with technologies to detect fatigue, the systems might have prevented or mitigated the severity of the fatigue-related crash. Therefore, given the likelihood that technologies to detect fatigue could make fatigued drivers more aware of their condition and given that driver fatigue is a major cause of or factor in accidents (as shown in the large truck crash causation study),[99] the Safety Board recommends that the FMCSA develop and implement a plan to deploy technologies in commercial vehicles to reduce the occurrence of fatigue-related accidents.

[99] FMCSA-RRA-07-017.

Rumble strips alert the driver when the vehicle travels over them, creating tactile and auditory stimuli. Rumble strips have been shown to be effective in reducing the number and severity of run-off-the-road crashes.[100] Rumble strips were located on the left and right shoulders near the Osseo accident site. Each rumble strip was 16 inches long and 7 inches wide, and the depression depth was approximately 0.5 inch. On the right side of I-94, they were offset from the line marking the beginning of the shoulder (where the vehicle left the roadway) by 2 feet 6 inches. Tire marks show that the vehicle's tires would have been in contact with the rumble strips for about 190 feet (about 2 seconds).[101] Tire marks also show that the Osseo truck began to curve back toward the pavement about 340 feet after it traveled over the right shoulder and entered the grassy area (about 3.5 seconds). The tire marks show that the truck had drifted off the road, traveled over the rumble strips and into the grassy side slope, and then, shortly thereafter, returned to the roadway. The Safety Board concludes that the fatigued truck driver was alerted by the audible and/or tactile signal made by traveling over the rumble strips and/or grassy slope, turned the vehicle back toward the roadway, and lost control of the truck-tractor semitrailer.

Technological systems for detecting fatigue, regardless of whether they are driver-based, vehicle-based, or environmental-based, are intended to be used as an "alarm" to which the driver responds by driving to a safe place to get some rest. Some have expressed concern that drivers could use the alarms as a mechanism to help them stay awake while continuing to drive despite being fatigued,[102] although drivers educated about the dangers of fatigue should be aware that such practices would put both them and the traveling public at risk. Another concern is that, once alerted to their fatigued state, drivers might have difficulty in finding an adequate place to rest.

Truck parking spaces and rest areas were the focus of a 2000 Safety Board report,[103] in which the Safety Board concluded that there were not enough adequate truck parking spaces available to accommodate traffic patterns in some locations. The Safety Board asked the FHWA, the FMCSA, the American Trucking Associations, Inc., the Owner-Operator Independent Drivers Association, the National Private Truck Council, and the National Association of Truck Stop Operators to create a comprehensive guide, available both on paper and in electronic format, for all truck drivers to use that would inform them of the location of all parking areas (both private and public) and the space availability (Safety Recommendations H-00-18 and -19, and H-00-21 through -24). In response, the

[100] (a) J.J. Hickey. (b) R.R. Marvin and D.J. Clark.

[101] Assuming the truck was traveling at a speed between 65 and 70 mph, the truck tractor would have traveled over the rumble strips for between 1.9 and 2.0 seconds.

[102] (a) Transportation Research Board (2000). (b) Peters and others (1999).

[103] National Transportation Safety Board, *Truck Parking Areas*, Special Investigation Report NTSB/SIR-00/01 (Washington, DC: NTSB, 2000).

FMCSA published a list of rest stops.[104] All but one of these recommendations are classified "Closed—Acceptable Action."[105]

With respect to the issue of adequate rest stops, the Safety Board also asked the FHWA to

> H-00-17
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> As part of the report to Congress on the Transportation Equity Act for the 21st Century section 4027, evaluate the benefits, related to truck parking, of eliminating the prohibition against private development of rest area facilities on interstates. Should this evaluation conclude that truck parking could be improved, obtain legislative authority to eliminate the prohibition where needed.

This recommendation is classified "Open—Acceptable Action." In correspondence with the Safety Board, the FHWA said it would evaluate options with the private sector. In its 2000 report on truck parking areas, the Safety Board also concluded that parking time limits for public rest areas can cause drivers to return to the roadway without obtaining adequate rest or to park unsafely on shoulders or ramps. The Safety Board asked several States to

> H-00-20
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> Once your State has ensured that adequate parking is available, eliminate or modify those time limits at public rest areas that can prevent truck drivers from obtaining adequate rest or redirect drivers to nearby parking facilities where they can obtain adequate rest.

Currently, the recommendation is classified as "Open—Acceptable Response" for Alabama, Minnesota, and Washington; "Open—Unacceptable Response" for Delaware, Illinois, Louisiana, Pennsylvania, Tennessee, and Virginia; and "Closed—Acceptable Response" for Florida, Georgia, Kentucky, Nebraska, New Jersey, South Carolina, and South Dakota.

Fatigue Education

Fatigue detection technologies and rumble strips are designed to alert the fatigued driver who is already on the roadway. Educational and regulatory efforts are intended to keep fatigued drivers off the roadways. The Safety Board has issued several recommendations related to education and driver fatigue. In 1989, the Safety Board issued an intermodal recommendation that asked the USDOT to

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[104] Available at <http://www.fmcsa.dot.gov/about/other/other-fmcsa-sites/links.htm>, accessed July 14, 2008.

[105] The Safety Board classified Safety Recommendation H-00-23 "Closed—No Longer Applicable" because the intent of the recommendation was satisfied by the published list of rest stops.

> <u>I-89-2</u>
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> Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest.[[106]]

In its 1995 study on fatigue in heavy truck accidents,[107] the Safety Board asked the FHWA to develop and disseminate a training and educational module to inform truck drivers of the hazards of driving while fatigued (Safety Recommendation H-95-5). In 1999, the Board asked the FHWA to ensure that the dangers of inverted sleep periods were discussed in the fatigue video being developed for motorcoaches (Safety Recommendation H-99-4a). The USDOT published a 1995 report, *Sharing the Knowledge: Department of Transportation Focus on Fatigue*, and produced two videotapes that addressed fatigue. The FHWA and the American Trucking Associations, Inc., adapted an aviation training module for use within the commercial driving industry. The USDOT also developed a train-the-trainer course on fatigue and fatigue countermeasures.[108] The FHWA was involved in the development and dissemination of the brochure *Awake at the Wheel*. Other organizations, including the National Sleep Foundation and the AAA Foundation for Traffic Safety, have also produced educational materials for use by CMV drivers. The FMCSA developed a motorcoach driver fatigue video that addressed the dangers of inverted duty and sleep periods. Safety Recommendations I-89-2, H-95-5, and H-99-4a are classified "Closed—Acceptable Action."

The FMCSA is currently involved in the development of a "North American Fatigue Management Program for Commercial Motor Carriers."[109] This project is a collaborative effort "aimed at reducing fatigue-related accidents and decreasing the personal and economic cost to drivers, companies, and worker's compensation programs and insurance carriers."[110] The final product, a "best practices manual," is intended to have several components, including the following:

[106] National Transportation Safety Board, ***Head-End Collision of Consolidated Rail Corporation Freight Trains UBT-506 and TV-61 Near Thompsontown, Pennsylvania, January 14, 1988***, Railroad Accident Report NTSB/RAR-89/02 (Washington, DC: NTSB, 1989).

[107] NTSB/SS-95/01 and NTSB/SS-95/02.

[108] The National Aeronautics and Space Administration developed an education and training module titled "Alertness Management in Flight Operations." Its three primary objectives were to explain (1) the current state of knowledge about the physiological mechanisms that underlie fatigue, (2) the misconceptions about fatigue, and (3) fatigue countermeasures. The aviation program's rationale was used as the basis of the FHWA/American Trucking Associations training module.

[109] NTSB staff communication with FMCSA staff on June 13, 2008.

[110] The research initiative is sponsored by the FMCSA, Alberta Transportation, Alberta Workers' Compensation Board, Commission de la Santé et de la Sécurité du Travail du Québec, Société de l'Assurance Automobile du Québec, and Transport Canada. The project is supported by the Alberta Motor Transport Association, American Transportation Research Institute, Association du Camionnage du Québec, Canadian Trucking Alliance, and Canadian and U.S. volunteer motor carriers and drivers taking part in operational tests.

- *Company Ownership of the Fatigue Management Plan (FMP)*. Such an outcome involves management support, as well as an empowered FMP-coordinating group within the company, which can provide guidance and support to the organization.
- *Education and Training*. Materials will provide general information on a variety of subjects including fatigue, sleep, and sleep disorders; health and wellness; and trip planning. The educational component will also include a system to track participant progress. In addition, refresher and supplemental materials, such as newsletters or updates, will be distributed to reinforce the information already learned and to ensure ongoing commitment to the program.
- *Scheduling Policies and Practices*. The company's existing scheduling policies and practices will be evaluated for inherent fatigue-related risk, and the principles of effective fatigue management will be applied while continuing to maintain effective service.
- *Sleep Disorders Screening and Treatment*. This section of the manual will provide guidance to carriers and drivers about medical factors that may contribute to workplace fatigue. Sleep disorders screening and treatment will be addressed.
- *Compliance and Review*. Evaluation of the quality and effectiveness of the program is to be ongoing. This will require data collection and incident reporting. Guidelines for followup action to incidents for communicating "lessons learned," as well as for implementing changes for future situations will be supplied in the FMP.

The North American Fatigue Management Program for Commercial Motor Carriers calls for evaluation of FMPs at the motor carrier level. Evaluation is intended to determine how well each FMP is working for its individual carrier. However, the FMCSA, as the Federal agency responsible for commercial vehicle safety, must also be involved in the evaluation of the FMPs to determine whether they successfully mitigate fatigue and how to make the programs more successful. The Safety Board recognizes that the North American Fatigue Management Program for Commercial Motor Carriers is currently being tested in an operational setting but considers that the assessment process should be continual. The Safety Board concludes that for FMPs to be successfully implemented by motor carriers over time, FMCSA oversight is needed. Therefore, the Safety Board recommends that the FMCSA develop and use a methodology that will continually assess the effectiveness of the FMPs implemented by motor carriers, including their ability to improve sleep and alertness, mitigate performance errors, and prevent incidents and accidents.

The carrier Whole Foods, which employed the truck driver involved in the Osseo accident, made available to its drivers brochures on various safety topics, including operator fatigue. It is unknown whether the accident truck driver ever read the Whole Foods brochures on operator fatigue, but the truck driver's failure to change his behavior to ensure that he did not drive while fatigued suggests that the motor carrier's fatigue education program was insufficient either in content or in application. In particular, it appears that the program was not supported by management strongly enough to impress upon Whole Foods drivers the risks associated with driving while fatigued and the necessity of applying fatigue information to work and rest practices. Further, the motorcoach driver involved in the 2004 Turrell, Arkansas, accident was given advance notice of the trip, but he did not properly alter his schedule to adjust to nighttime driving. There is no evidence that the Turrell accident driver ever received fatigue training or was provided informational material on fatigue. The Safety Board recognizes that the North American Fatigue Management Program for Commercial Motor Carriers being developed by the FMCSA and others will be available to motor carriers and that it will contain components to combat fatigue. However, the Safety Board is also aware that about 66 percent of motor carriers have fleet sizes of 1 to 3 vehicles, and these carriers may not have the resources necessary to support the FMP.[111]

Based on the fatigue status of the Osseo and Turrell drivers, the Safety Board is concerned that fatigue educational materials are currently failing to reach, or to positively affect the behaviors of, some commercial drivers. It is in the best interest of the motor carrier to ensure that educational materials are available to drivers and in the best interest of drivers to act responsibly and ensure that they are rested before driving a commercial vehicle. The Safety Board concludes that although fatigue educational materials are becoming more widely available through the efforts of government agencies and many motor carriers, accident evidence suggests that some commercial drivers, like the Osseo truck driver, remain unaffected by the fatigue education message. The actions of the Osseo truck driver indicate that he did not take the Whole Foods fatigue education program seriously enough to alter his behavior to ensure that he obtained adequate rest before driving. Therefore, the Safety Board recommends that Whole Foods implement a comprehensive fatigue education program that requires company management to ensure that employees understand the risks of driving while fatigued and comply with fatigue guidelines. In addition, the Safety Board will draft articles for inclusion in the publications of motor carrier and commercial driver organizations describing the circumstances of this accident, the dangers of driving while fatigued, the problem of drivers disregarding fatigue warnings, and motor carriers' and drivers' responsibilities regarding fatigue.

Hours-of-Service Compliance

Federal regulations (49 CFR 395.8) require drivers to maintain a record of their status, in duplicate, either by using an approved log grid or an automatic on-board recording device, and to keep the records current. The truck driver in the Osseo accident was not maintaining a driver log. Furthermore, Federal

[111] See <http://ai.fmcsa.dot.gov/CarrierResearchResults/PDFs/LS50B901_03_04_02.pdf>, accessed June 19, 2008.

regulations (49 CFR 395.8 [a]) require that motor carriers require their drivers to record their duty status for each 24-hour period, using either an approved log grid or an automatic on-board recording device. In the Osseo accident, a postaccident compliance review found that the motor carrier Whole Foods had violated several HOS regulations.[112] Postaccident compliance reviews of the motor carriers involved in the 2006 Lake Butler, Florida, and 2004 Turrell, Arkansas, accidents indicated that those carriers also had violated logbook regulations.

For more than 30 years, the Safety Board has been issuing recommendations with respect to its concern that driver logs do not provide an efficient and reliable means of tracking the number of hours a commercial driver drives. In 1977, the Safety Board issued its first recommendation on the use of on-board recording devices for commercial vehicles (Safety Recommendation H-77-32). Since then, the Safety Board has issued additional recommendations concerning the use of on-board recorders (Safety Recommendations H-90-28 and -48 and Safety Recommendations H-98-23 and -26), but they have not been implemented.[113] Most recently, during an investigation of a multiple-vehicle accident that took place near Chelsea, Michigan,[114] the Safety Board discovered two versions of the driver's logs. The Safety Board recommended to the FMCSA that it

> H-07-41
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> Require all interstate commercial vehicle carriers to use electronic on-board recorders that collect and maintain data concerning driver hours of service in a valid, accurate, and secure manner under all circumstances, including accident conditions, to enable the carriers and their regulators to monitor and assess hours-of-service compliance.

In its initial response, the FMCSA noted that it had a rulemaking on electronic on-board recorders (EOBR) under way; the notice of proposed rulemaking (NPRM) had been published on January 18, 2007.[115] The NPRM focused on three elements: (1) performance-oriented standards for EOBRs, (2) mandatory use of EOBRs only for those motor carriers found to exhibit a pattern of violations of HOS regulations, and (3) development of incentives expected to encourage voluntary industrywide use of EOBRs. In its April 18, 2007, comments concerning this NPRM, the Safety Board expressed its general satisfaction regarding the performance standards for

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[112] The violations included that Whole Foods had required or permitted a property-carrying CMV driver to drive more than 11 hours, required or permitted a property-carrying CMV driver to drive after the end of the 14th hour after coming on duty, required or permitted a property-carrying CMV driver to drive after having been on duty more than 70 hours in 8 consecutive days, made a false report of records of duty status, failed to require a driver to prepare a record-of-duty status, and failed to preserve a driver's record-of-duty status for 6 months.

[113] These four recommendations are all classified "Closed—Unacceptable Action."

[114] National Transportation Safety Board, *Rear-End Chain Reaction Collision, Interstate 94 East, Near Chelsea, Michigan, July 16, 2004*, Highway Accident Brief NTSB/HAB-07/01 (Washington, DC: NTSB, 2007).

[115] USDOT Docket No. FMCSA-2004-18940.

EOBRs, its disappointment that the NPRM did not propose mandatory EOBR use by all operators subject to HOS regulations, and its concern that the incentives proposed in the NPRM would not be strong enough to override the financial motivation that some carriers and drivers have for continuing to circumvent the HOS regulations and not use EOBRs. The Safety Board urged the FMCSA to revise the NPRM to require that all motor carriers subject to the HOS regulations install and use EOBRs. According to the USDOT rulemaking webpage, a final rule is expected by December 2008.[116]

Also in the Chelsea report, the Safety Board recommended that the FMCSA

> H-07-42
>
> As an interim measure and until industrywide use of electronic on-board recorders is mandated, as recommended in Safety Recommendation H-07-41, prevent log tampering and submission of false paper logs by requiring motor carriers to create and maintain audit control systems that include, at a minimum, the retention of all original and corrected paper logs and the use of bound and sequentially numbered logs.

In its response to the recommendation, the FMCSA indicated it did not believe an interim rulemaking was necessary. Instead, the FMCSA believed it would be better to focus its efforts on the EOBR NPRM and the proposed mandate to require EOBRs on only a limited number of motor carriers, which it said would advance safety more than efforts to improve handwritten records. The Safety Board is drafting a reply to the FMCSA.

The Safety Board continues to believe that drivers should maintain reliable, accurate, and verifiable status-of-duty records and that motor carriers are responsible for ensuring that records are maintained. EOBRs would ensure that drivers and carriers have accurate and valid HOS information available to them. Based on the Osseo investigation, the Safety Board concludes that the Osseo truck driver and the Midwest distribution center of Whole Foods failed in their responsibilities to maintain status-of-duty records. The Safety Board further concludes that mandating the use of EOBRs by all interstate commercial vehicle carriers would ensure the availability of valid, accurate, and secure HOS data, which could result in increased compliance with HOS regulations. Implementation of Safety Recommendation H-07-41 would ensure that motor carriers such as Whole Foods have EOBR-collected HOS data available for all their drivers, which would enable the carriers to monitor and assess the HOS compliance of their drivers quickly and efficiently. Therefore, the Safety Board encourages the FMCSA to implement Safety Recommendation H-07-41 as soon as possible.

[116] See <http://regs.dot.gov/rulemakings>, accessed July 14, 2008.

Stability Control Systems

As noted previously, the Osseo truck-tractor semitrailer drifted off the side of the road, traveled over the rumble strips, onto the grass shoulder, and then turned back to the roadway, where it overturned onto its right side. The truck traveled 190 feet over the rumble strips and another 340 feet in the grassy area. The side slopes parallel to I-94 for about 140 feet from the start to the end of the tire furrows on the grassy slope were predominantly recoverable (side slopes that are about 4:1) or flatter. None were critical (side slopes steeper than 3:1). However, this classification is based on vehicles with relatively low centers of gravity (that is, passenger cars) and a fully alert driver who can steer and/or brake the vehicle as effectively as possible to return to the roadway or to stop. Trucks have higher centers of gravity, and the circumstances of the Osseo truck accident included a fatigued driver just alerted by the noise and/or vibration of the rumble strips, who was not braking or steering optimally. Furthermore, the grassy slope had a lower coefficient of friction than the pavement, and the accident occurred at night. Therefore, the Safety Board concludes that the side slopes parallel to I-94 where the truck left the roadway were predominantly in the recoverable category; however, the circumstances of this accident, including a fatigued driver, a grassy slope with a lower coefficient of friction than the pavement, and night-time travel, made safely returning to the roadway or traversing to the bottom of the slope and stopping very difficult.

The Safety Board simulated the truck's departure from and return to the roadway. The simulation showed that the truck could not have had a greater travel speed than 60 mph when returning to the roadway without experiencing a rollover. The simulation incorporating an ESC system did not increase the maximum speed above 60 mph, indicating that such a system would not have prevented the accident. The Safety Board concludes that, given the particular circumstances of the Osseo accident, an ESC system would not have prevented the truck from overturning.

ESC systems function by monitoring a vehicle's speed, steering wheel angle, yaw rate, and lateral acceleration. These data are used to enhance the directional and roll stability of the vehicle. Directional stability directly affects the vehicle's ability to follow a driver's steering input. If the driver's input is not being followed, ESC systems automatically take action to assist the driver by applying braking at various wheels and possibly reducing the engine torque.[117] ESC systems enhance roll stability and prevent rollovers by slowing the vehicle when a driver enters a curve at too high a speed. Even with an ESC system, the vehicle may not be able to follow the path indicated by the driver's steering input if this path results in directional or roll instability.

[117] J.N. Dang, *Statistical Analysis of the Effectiveness of Electronic Stability Control (ESC) Systems – Final Report*, DOT HS 810 794 (Washington, DC: NHTSA, July 2007).

Roll stability control (RSC) systems are another type of safety system marketed for commercial vehicles. These are ESC systems without the directional stability function. RSC systems do not require yaw rate or steering wheel sensors. Lack of these sensors can delay the detection of unstable maneuvers. Roll stability advisors are passive systems that inform the driver about rollover risks. Rather than provide a warning of a potential risk, they provide an advisory message after an event has occurred, with the intent of improving a driver's performance.

A USDOT-sponsored field operational test of a roll advisor and control (RA&C) system was conducted to evaluate the benefits of the system in preventing rollover crashes. RA&C systems have two components. The first component is the roll stability advisor, which is an educational tool for drivers; the second is the RSC system, which takes partial, momentary control of the vehicle if it deems that a serious rollover threat is developing. Under conditions similar to those observed in the field operational test, the RA&C system is expected to prevent 20 percent of rollover crashes caused by excessive speed in a curve.[118]

NHTSA is studying stability control systems on heavy vehicles. In the first phase of this research project, NHTSA identified several heavy truck rollover accident scenarios based on accident statistics and used subjective evaluation to determine whether a stability control system would have prevented the accident. The second phase of the project is currently under way in which computer simulation is used to evaluate the effectiveness of stability control in each accident scenario. Both roll stability control and ESC systems are being evaluated to determine if one particular system could be more effective in preventing rollovers. This project is expected to be completed later this year.

According to the FARS and General Estimates System data, 15,000 large trucks were involved in documented rollover crashes in 2006.[119] Stability control systems can help reduce fatalities and injuries resulting from heavy truck rollover accidents, as well as reduce costs and traffic congestion associated with rollovers. The Safety Board is pleased that NHTSA is evaluating stability control systems for large trucks and will continue to monitor the progress of NHTSA's efforts.

Collision of Motorcoach With Overturned Truck-Tractor Semitrailer

The motorcoach driver possessed a valid Wisconsin class A CDL with a restriction requiring corrective lenses while driving; the license also had hazardous materials, tank truck, passenger, and school bus endorsements. Further, the

[118] Battelle, *Final Report Evaluation of the Freightliner Intelligent Vehicle Initiative Field Operational Test* (September 2003), prepared for the USDOT, under contract no. DTFH61-96-C-00077, work order 7718.

[119] National Highway Traffic Safety Administration, *Traffic Safety Facts 2006: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System* (Washington, DC: NHTSA, 2007).

motorcoach driver possessed a valid medical certificate. Therefore, the Safety Board concludes that although the motorcoach driver did not wear corrective lenses on the night of the accident, as required, he was otherwise qualified and fit to drive the motorcoach.

Truck Visibility

After the Osseo truck left the roadway and entered the earthen, sloped roadside, the driver steered it back to the roadway, where it overturned, blocking both westbound lanes. When the truck overturned, the bottom of the truck-tractor semitrailer faced westbound vehicles.

Safety Board investigators examined the headlight and taillight assemblies of the truck tractor at Safety Board headquarters. Of the 10 light bulbs removed from the front of the bus, only the left and right side marker lights were found to have stretched filaments.[120] The filaments in these lights were also fractured. Broken filaments were found in the left fog light, right-front low-beam headlight, and right fog light.

The left and right red-encased taillights were double-filament lamps, with one filament smaller than the other. In the right side taillight, the larger filament was broken, and the smaller one was stretched and broken. In the left side taillight, the larger filament was intact, and the smaller filament was stretched and broken.

When a light bulb's filament is stretched, it indicates that the bulb was illuminated when an outside force, such as a crash, affected it, deforming or stretching the filament. Broken filaments suggest that the light bulb was not illuminated during an impact. Hot filaments cannot fracture before stretching, and it is unlikely that one impact could result in both stretching and fracturing.

The Osseo truck tractor was involved in two separate impacts: the one that occurred when it fell onto its right side and the one caused by the motorcoach colliding with it. The evidence of the stretching of the light bulb filaments indicates that when the truck overturned, its lights were illuminated. The truck driver said he turned off the tractor's ignition after the overturn. Although this action depowered the engine, it is possible that the tractor's lighting systems continued to receive power. The fracturing of the light bulb filaments, however, indicates that when the motorcoach struck the truck, the truck's lights were off. The investigation found no evidence that any of the tractor lights were illuminated when the motorcoach struck it.

[120] The headlight assemblies consisted of a low-beam bulb, a high-beam bulb, a daytime running and turn signal combination bulb, a side marker bulb, and a fog light bulb.

As required by Federal regulations, the truck-tractor semitrailer had retroreflective tape and LED assemblies on the trailer sides and back. However, the retroreflective tape and LED lights would not have been visible to the motorcoach driver because when the truck-tractor semitrailer overturned, it slid to a stop with its underside facing the westbound traffic.

Motorcoach Lighting

The motorcoach was equipped with four headlights—two outboard low-beam headlights and two inboard high-beam headlights. Two of the headlight units survived the impact. These headlight assemblies consisted of a three-blade electrical connector attached to a dual-filament lamp. These units were configured in the same way as the low-beams from an exemplar headlight; therefore, the headlight units removed from the accident motorcoach were low-beam lights.

The light bulbs had two filaments. Examination of the motorcoach headlights revealed stretching to one filament of a headlight bulb on the right side of the motorcoach. Both lamp filaments in the low-beam unit and the single-unit filament in the high-beam unit are connected through a common ground. When the low beams are activated, power is supplied to only one of the dual filaments within the low-beam sealed unit. When the high beams are activated, power continues to be supplied to the low-beam filament already in use, and the second filament of the dual-filament assembly receives power as well. Because the electrical connection to this filament is paired to the high-beam unit, power is also applied to the high-beam lamp's filament. The assembly from the right side lamp showed stretching to only one filament, indicating that it was the only one receiving power at the time of the crash; thus, it can be deduced that the motorcoach's low-beam headlights were on at the time of the crash.

A visibility study that investigators conducted 5 days following the accident showed that, on the night of the study, a hazard in the right lane that would prompt a driver to start reducing vehicle speed by braking could be seen from 329 feet under low-beam headlight conditions. Under the high-beam configuration, a hazard in the right lane that would cause a driver to begin braking could be seen from 786 feet.

The highway had no artificial lighting in the vicinity of the accident, so the roadway itself was essentially dark at the time of the motorcoach's collision with the overturned truck.

Therefore, the Safety Board concludes that the darkness, the absence of lighting on the truck-tractor semitrailer, and the motorcoach driver's use of low-beam headlights made it difficult for the motorcoach driver to see the overturned truck.

Motorcoach Driver

Vision. The motorcoach driver had distant visual acuity (uncorrected) of slightly better than 20/50 in his right eye, of 20/50 in his left eye, and of slightly worse than 20/40 in both eyes together. His best corrected visual acuity was just under 20/25 in his right eye and just under 20/20 in his left eye. Federal regulations require drivers to have distant visual acuity of at least 20/40 in each eye without corrective lenses or visual acuity separately corrected to 20/40 or better with corrective lenses, distant binocular acuity of at least 20/40 in both eyes with or without corrective lenses, field of vision of at least 70 degrees in the horizontal meridian in each eye, and the ability to recognize colors of traffic signals and devices showing standard red, green, and amber (49 CFR 391.41). Although the driver was required to wear corrective lenses while driving, the driver's vision was close to meeting visual standards without corrective lenses. After the accident, investigators found the driver's eyeglasses in his bag; thus, he had not been wearing them at the time of the accident.

According to the June 2005 records of the driver's ophthalmologist, the driver had very early cataract formation in both eyes, although the cataracts were not at a stage at which surgery might be recommended. Early cataracts can substantially decrease visual perception, particularly under conditions of glare or low contrast (such as at night).[121] An estimated 20.5 million (17.2 percent of) Americans older than 40 years have a cataract in at least one eye, and this number is expected to increase to 30.1 million by 2020.[122]

The truck-tractor semitrailer had come to rest with its bottom facing oncoming traffic. There were no lights and no reflective surfaces on the bottom of the vehicle. Nor were there areas of high contrast or of significant contrast with the asphalt surface of the road. Based on the results of the visibility study, performed by very slowly moving an exemplar motorcoach toward the overturned truck, the earliest distance at which a hazard in the motorcoach's lane could be detected by individuals with 20/20 vision under low-beam headlight conditions was between 259 feet and 329 feet. Given the lack of reflective surfaces on the bottom of the combination unit, the initial identification of the road hazard was primarily dependent on the point of the vehicle's entry into the cone of light, which for the exemplar motorcoach occurred at 271 feet. The visibility testing showed that the earliest distance at which a hazard in the motorcoach's lane that warranted emergency braking could be detected was 227 feet. Thus, even a driver with 20/20 vision would have had only 227 feet in which to react to the hazard and brake to avoid it. If the motorcoach had been traveling at 70 mph and the driver saw the overturned truck at 227 feet and recognized it as a hazard, he would have

[121] See, for instance: (a) D.B. Elliott and P. Situ, "Visual Acuity Versus Letter Contrast Sensitivity in Early Cataract," *Vision Res*. Jun 38(13) (1998): 2047-52, and (b) I.A. Adamsons, S. Vitale, W.J. Stark, and G.S. Rubin, "The Association of Postoperative Subjective Visual Function With Acuity, Glare, and Contrast Sensitivity in Patients with Early Cataract," *Arch Opthalmol*, May 114 (5) (1996): 529-536.

[122] The Eye Diseases Prevalence Research Group, "Prevalence of Cataract and Pseudophakia/aphakia Among Adults in the United States," *Archives of Ophthalmology* 122 (2004): 487-494.

had only 2.2 seconds (at that speed) in which to respond before impact. A review of the literature on brake application published in 2000 suggests a roughly 1.5-second average perception-to-brake-application time under surprise conditions.[123] Additionally, it takes another 0.3 to 0.5 second for the brake to be depressed and reach full pressure, and time is also needed for the vehicle to begin to slow.

Although there were no skid marks at the Osseo accident site, the filaments of the "Stop Lamps" indicator bulb on the motorcoach indicator panel showed significant stretching, suggesting that the light was on at the time of the collision, and therefore, that the motorcoach brakes were applied. Several motorcoach passengers indicated that they felt a sudden deceleration of the motorcoach just before impact.

Therefore, the Safety Board concludes that the motorcoach driver saw the overturned truck and initiated braking prior to impact; however, even a driver with ideal vision most likely would not have been able to react to the unanticipated road hazard in time to slow the motorcoach sufficiently to alter the severity of the accident. Consequently, the Safety Board further concludes that the motorcoach driver's early cataract formation most likely did not affect the outcome of this accident. Nevertheless, estimates indicate that the incidence of cataracts among drivers is likely to increase in the coming years, making the possible effect of cataracts on the capabilities of CMV drivers a source of concern for the Safety Board.

The Safety Board considers the medical evaluation of commercial drivers to be an important safety issue, and it is listed on the Safety Board's Most Wanted List of Transportation Safety Improvements.[124] Safety Recommendations H-01-19 and -20, which were issued to the FMCSA as a result of a 1999 motorcoach accident investigation involving a medically unqualified driver,[125] address medical regulations and guidance as follows:

> <u>H-01-19</u>
>
> Develop a comprehensive medical oversight program for interstate commercial drivers that contains the following program element: Medical certification regulations are updated periodically to permit trained examiners to clearly determine whether drivers with common medical conditions should be issued a medical certificate.

[123] M. Green, "How Long Does It Take To Stop? Methodological Analysis of Driver Perception-Brake Times," *Transportation Human Factors* 2(3), (2000): 195-216.

[124] Safety Recommendations H-01-17 through -24 are on the Safety Board's Most Wanted List. They ask the FMCSA to establish a comprehensive medical oversight program for interstate commercial drivers, ensure that examiners are qualified and know what to look for, track of all medical certificate applications, enhance oversight and enforcement of invalid certificates, and provide mechanisms for reporting medical conditions.

[125] National Transportation Safety Board, *Motorcoach Run-Off-The-Road, New Orleans, Louisiana, May 9, 1999*, Highway Accident Report HAR-01/01 (Washington, DC: NTSB, 2001).

> H-01-20
>
> Develop a comprehensive medical oversight program for interstate commercial drivers that contains the following program element: Individuals performing examinations have specific guidance and a readily identifiable source of information for questions on such examinations.

The Safety Board has acknowledged the progress the FMCSA has made to update the physical requirement standards but has expressed its concern about the limited progress the FMCSA has made toward developing a National Registry of Certified Medical Examiners and a tracking system to document driver status for verification by subsequent examiners. Safety Recommendation H-01-19 is classified "Open—Acceptable Response," and Safety Recommendation H-01-20 is classified "Open—Unacceptable Response," pending action to improve the medical certification process for CMV drivers.

The FMCSA has formed a Medical Review Board (MRB), which convened for the first time on August 31, 2006. The MRB holds quarterly meetings. MRB members work with research panels to examine medical issues affecting commercial drivers concerning the development of new science-based standards and guidelines for the physical qualifications that CMV drivers and operators must meet. According to the FMCSA, current topics being reviewed by the MRB include diabetes mellitus, prescription medications, cardiovascular disease, neurologic disease, sleep disorders, musculoskeletal disease, psychiatric disease, renal disease, infectious disease, injury, postsurgical injuries, and vision and hearing.[126]

At its April 7, 2008, meeting, the MRB discussed vision and CMV safety. Regarding cataracts, the MRB concluded, "There is insufficient evidence to modify the current standard to include the possible impact of cataracts on CMV driving ability."[127] However, a presentation at the meeting noted that, "It is plausible for individuals with cataracts to be at increased risk for a crash because of increased glare, reduced visual acuity, and the potential of developing diplopia." The FMCSA is currently considering regulatory development on the vision standard. Additionally, the FMCSA has stated that it intends to provide guidance on vision requirements for commercial drivers, including cataracts, in the upcoming medical examiner handbook.[128] The Safety Board is pleased that the FMCSA is working to address the possible issue of cataracts in the commercial driver population.

Fatigue. At the time of the accident, the motorcoach driver had been awake for at least 18 hours. He had been driving for about 3 hours before the accident. The accident occurred at 1:59 a.m., a time at which the body is predisposed to sleep, and the motorcoach driver had been sleeping during this period in the 2 days preceding the accident. These factors could have made the driver susceptible to fatigue.

126 Per <http://www.mrb.fmcsa.dot.gov/meeting.htm>, accessed July 16, 2008.

127 See <http://mrb.fmcsa.dot.gov/040708_meeting_present.htm>, accessed August 4, 2008.

128 E-mail communication from FMCSA representative to Safety Board staff, August 12, 2008.

As previously noted, the motorcoach driver braked the vehicle before colliding with the overturned truck. The braking activity indicates that the motorcoach driver was sufficiently alert to see an obstruction in the roadway and to attempt to stop the vehicle. The Safety Board concludes that although the motorcoach driver's schedule provides the possibility that his performance could have been impaired by fatigue, the visibility circumstances of the accident and the braking evidence indicate that he was awake and alert but could not see the wreckage in time to prevent the collision with the overturned truck.

Age. The motorcoach driver was 78 years old. Research has shown that some mental and physical abilities tend to decline with age.[129] For example, some older drivers show declines in their ability to clearly differentiate visual stimuli, particularly under low illumination and in low-contrast situations, as well as in their ability to identify objects in motion and in the presence of glare. Research findings regarding reaction times are difficult to interpret, but most research indicates that older people, on average, respond more slowly (estimated to be about 0.3 second more slowly) than younger people do.[130] Nevertheless, given the circumstances of this accident, investigators do not consider that the driver's age made the motorcoach's collision with the overturned truck-tractor semitrailer any less avoidable. As stated previously, a driver with 20/20 vision would have had 227 feet in which to see and react to the overturned truck. Assuming a traveling speed of 70 mph, such a driver would have had about 2.2 seconds in which to take action before the collision occurred. The average projected reaction time to an unexpected situation is about 1.5 seconds;[131] this, combined with the 0.3 to 0.5 second needed for brake rise time[132] and the additional time needed for the vehicle to decelerate, makes it very unlikely that a driver of any age or ability would have been able to avoid, or even significantly lessen the severity of, the accident.

Motorcoach Brakes

During the postaccident inspection, two of the six brakes on the motorcoach were found to be defective and out of adjustment. Both of these out-of-adjustment brakes were on the drive axle of the motorcoach and had automatic slack adjusters that dated to the motorcoach's original manufacture, indicating that they had been in use for over 12 years. The out-of-adjustment condition would have placed the motorcoach out of service, according to CVSA criteria.

[129] (a) A.J. McKnight, "The Freedom of the Open Road: Driving and Older Adults," *Generations* Vol. 27, No. 2 (Summer 2003). (b) D.W. Eby, D.A. Trombley, L.J. Molnar, and J.T. Shope, *The Assessment of Older Drivers' Capabilities: A Review of the Literature*, UMTRI-98-24 (Ann Arbor, MI: UMTRI, August 1998).

[130] M. Green, "How Long Does It Take To Stop? Methodological Analysis of Driver Perception-Brake Times."

[131] M. Green.

[132] The *brake rise time* is the time it takes for the pedal to be fully depressed and the brake system to reach full pressure.

At a 100-psi brake application, the motorcoach would have decelerated at a rate of 0.369 *g*, given the condition of the brakes. If all the brakes had been within adjustment and adjusted to achieve the maximum amount of brake force, the preimpact deceleration rate would have been 0.587 *g*. Assuming that the motorcoach was traveling at a speed of 70 mph and that the brakes were in the condition they were at the time of the accident, the motorcoach would have needed approximately 442 feet in which to come to a complete stop. If the brakes had been in ideal adjustment, the motorcoach would have needed approximately 278 feet in which to stop.

WISDOT placed this motorcoach out of service 4 months before the accident because the drive axle brakes were out of adjustment. The motorcoach company attempted to solve the problem by manually adjusting the automatic slack adjusters. However, automatic adjusters should be manually adjusted only as a temporary measure to correct the adjustment in an emergency, because this procedure usually does not fix the underlying problem, making it probable that the brakes will soon be out of adjustment again. In this case, the motorcoach's brakes most likely went out of adjustment shortly after the manual adjustment and remained so until the accident. The Safety Board concludes that improper maintenance of the brake system on the part of the motor carrier Chippewa Trails resulted in two out-of-adjustment drive axle brakes, which diminished the braking force available to slow the motorcoach, but this condition likely did not contribute to the accident.

The Safety Board addressed the issue of improperly maintained automatic slack adjusters most recently in its investigation of an accident that took place in Glen Rock, Pennsylvania, in which a dump truck with out-of-adjustment slack adjusters was unable to stop on a steep downgrade and collided with four cars and three pedestrians.[133] Two people were killed and several sustained injuries. As a result, the Safety Board made a series of recommendations to improve the maintenance and inspection of automatic slack adjusters.[134] Specifically, the Safety Board asked the FMCSA and the CVSA, respectively, to

> H-06-1
>
> Work with the Commercial Vehicle Safety Alliance to develop and add to the North American Standard Inspection training materials a module that emphasizes that manually adjusting automatic slack adjusters is dangerous and should not be done, except during installation or in an emergency to move the vehicle to a repair facility, because manual adjustment of this brake component (1) fails to address the true reason why the brakes are not maintaining adjustment, giving the operator a false sense of security about the effectiveness of the brakes, which are likely to

[133] National Transportation Safety Board, *Collision Between Ford Dump Truck and Four Passenger Cars, Glen Rock, Pennsylvania, April 11, 2003*, Highway Accident Report HAR-06/01 (Washington, DC: NTSB, 2006).

[134] The Osseo accident occurred before these recommendations were issued.

> go out of adjustment again soon, and (2) causes abnormal wear to the internal adjusting mechanism for most automatic slack adjusters, which may lead to failure of this brake component.
>
> H-06-7
>
> Work with the Federal Motor Carrier Safety Administration to develop and add to the North American Standard Inspection training materials a module that emphasizes that manually adjusting automatic slack adjusters is dangerous and should not be done, except during installation or in an emergency to move the vehicle to a repair facility, because manual adjustment of this brake component (1) fails to address the true reason why the brakes are not maintaining adjustment, giving the operator a false sense of security about the effectiveness of the brakes, which are likely to go out of adjustment again soon, and (2) causes abnormal wear to the internal adjusting mechanism for most automatic slack adjusters, which may lead to failure of this brake component.

In 2006, the FMCSA said it would work with the CVSA to modify the North American Standard Inspection training materials to include a module about the potential safety risks associated with manually adjusting automatic slack adjusters. The CVSA has notified the Safety Board that, in June 2007, the information in module 6 of the North American Standard Inspection training materials was updated to include the Board's recommended language to aid CVSA-certified inspectors who are not qualified brake inspectors pursuant to 49 CFR 396.25, nor who manually adjust brakes, when discussing the proper function and care of automatic slack adjusters and their relation to the foundation brake systems with drivers during a roadside inspection. The CVSA Vehicle Committee petitioned the FMCSA to amend 49 CFR 393.47(e) and 393.53 to require that an out-of-adjustment automatic slack adjuster constitute violation of both sections. The CVSA Information Systems Committee submitted a request to the FMCSA to add a warning to the ASPEN Inspection Report regarding a brake adjustment violation on any vehicle that is required to be equipped with a self-adjusting brake system; the advisory will be included in the next ASPEN update in September 2008. Safety Recommendation H-06-1 is classified "Open—Acceptable Response." Safety Recommendation H-06-7 to the CVSA remains classified "Open—Await Response," while the Safety Board considers the CVSA's actions in response to these recommendations.

Despite the progress being made on the recommendations noted above, the Safety Board remains concerned that brakes with automatic slack adjusters are still being manually adjusted. Drivers and motor carriers need to be reminded that automatic slack adjusters should only be manually adjusted at installation or under emergency conditions and that manually adjusting the slack adjusters does not fix the underlying problem with the brakes. Therefore, the Safety Board will draft an article for inclusion in the CVSA's quarterly publication *Guardian* on the dangers associated with manually adjusting automatic slack adjusters.

Collision Warning Systems

As has been stated, it would have been difficult for any driver to identify the overturned truck in the highway because there was no highway lighting in the vicinity, the truck's lights were off, and its retroreflective markings were invisible to approaching traffic. No skidmarks were found at the accident site, but examination of the indicator panel light bulbs in the motorcoach and motorcoach occupant recollections strongly indicate that the driver was applying the brakes at the time of the collision with the overturned truck. It is not known how long the motorcoach brakes were applied.

CWSs are designed to warn the driver of slowed or stopped objects in the vehicle's forward path. Commercially available systems sound an initial alert at 350 feet of the detected obstacle. Additional alerts are given as the time to collision decreases. For a stationary or stopped vehicle ahead, the highest warning level is given within 220 feet of the object.

Table 8 shows the change in speed that the motorcoach could have achieved if a CWS warning had been given and the driver had begun to take action at 220 feet. The table shows the impact speeds possible given a reaction time of 1.5 seconds;[135] a brake rise time of 0.5 second; and an initial motorcoach speed of 70 mph, based on the WSP's estimate of the motorcoach's speed. The calculations used to create the table also considered the condition of the brakes on the motorcoach at the time of the accident and brakes in ideal condition.

Table 8. Estimated change in Osseo motorcoach's velocity, assuming CWS warning was given and heeded at 220 feet.

Driver's reaction time (seconds)	Brake rise time (seconds)	Brake condition	Initial speed (mph)	Final speed (mph)	Speed reduction (mph)
1.5	0.5	At the time of the accident	70.0	68.8	1.2
1.5	0.5	Ideal	70.0	68.1	1.9

As can be seen, the reduction in speed possible, given the factors that must be considered, would have been less than 2 mph, even had the Osseo motorcoach's brakes been in ideal condition.

135 M. Green.

If the Osseo motorcoach driver had been cued and had responded to an initial CWS warning at 350 feet rather than 220 feet, the possible reduction in speed would have been greater. (See table 9.)

Table 9. Estimated change in Osseo motorcoach's velocity, assuming CWS warning was given and heeded at 350 feet.

Driver's reaction time (seconds)	Brake rise time (seconds)	Brake condition	Initial speed (mph)	Final speed (mph)	Speed reduction (mph)
1.5	0.5	At the time of the accident	70.0	57.5	12.5
1.5	0.5	Ideal	70.0	48.5	21.5

Nevertheless, given the existing condition of the Osseo motorcoach's brakes, the impact speed could still have been as high as 57.5 mph, even with a 350-foot warning distance. This is mainly because the CWS only alerts the driver to the hazard; the driver still needs time in which to detect and react to the hazard.

Some CWSs are equipped with an automatic braking system that will actively brake the vehicle if a collision is imminent. To date, active braking has not been coupled with CWS for commercial vehicles. Instead, the active safety systems are part of the ACC. Hypothetically, if the Osseo motorcoach had been equipped with a CWS that included an active braking system, the driver's reaction time would not have been a factor—only the brake rise time would have contributed to the distance traveled before maximum braking was achieved. (See table 10.)

Table 10. Estimated change in Osseo motorcoach's velocity, assuming CWS warning was given at 350 feet and CWS had active braking system.

Brake rise time (seconds)	Brake condition	Initial speed (mph)	Final speed (mph)	Speed reduction (mph)
0.5	At the time of the accident	70.0	40.0	30.0
0.5	Ideal	70.0	0.0	70.0

In this circumstance, with an active braking activation at 350 feet, if the Osseo motorcoach's brakes had been in ideal condition, the motorcoach would have had sufficient distance to stop before impact, and the second event of the Osseo accident sequence—which resulted in multiple fatalities—would have been prevented. Therefore, the Safety Board concludes that a CWS with active braking might have prevented, or at least lessened the severity of, the Osseo motorcoach's impact with the overturned truck.

CWS technology could also have assisted the driver in the Lake Butler, Florida, accident. Although it is probable that the truck driver whose truck collided with the passenger car and the school bus in that accident was asleep, or at least driving in a state of reduced alertness due to fatigue, a CWS could have alerted the truck driver that vehicles were in the roadway ahead. Analysis shows that had a hard brake application been made to the Lake Butler combination unit at a speed of 60 mph, it would have been able to come to a complete stop in approximately 265 feet. Thus, had the Lake Butler truck been equipped with a system that sounded a warning at 350 feet of detection and had the driver been alert enough to comprehend a CWS alarm notifying him that the school bus and passenger car were stopped ahead, he could have stopped his vehicle in 265 feet. This would have left the driver with 85 feet, which he would have needed to perceive and react to the warning. For the truck traveling at 60 mph, 85 feet would have afforded about 1 second of reaction time. Thus, a CWS might not have provided the fatigued or asleep Lake Butler driver with sufficient time to react to the warning, brake the vehicle, and prevent the accident, but it might have provided enough time for him to react, brake, and lessen the severity of the accident, or enough time to avoid the collision through steering inputs.

In 1995, the Safety Board investigated a multiple-vehicle rear-end collision that occurred during localized fog on Interstate 40 near Menifee, Arkansas.[136] As a lead vehicle entered the fog, it slowed from 65 mph to between 35 and 40 mph; then, it was struck in the rear. Subsequent collisions occurred as vehicles drove into the wreckage area at speeds varying from 15 to 60 mph. Eight loaded truck-tractor semitrailer combination units and one light-duty delivery van were involved. Three truck drivers, one passenger, and the van driver were killed. One truck driver received a minor injury and four truck drivers were not injured. As a result, the Safety Board asked the USDOT to

> <u>H-95-44</u>
>
> Sponsor, in cooperation with the Intelligent Transportation Society of America, fleet testing of collision warning technology through partnership projects with the commercial carrier industry. Incorporate testing results into demonstration and training programs to educate the potential end-users of the systems.

At the time the recommendation was issued, the USDOT had no plans for conducting operational testing of CWS. The Safety Board classified Safety Recommendation H-95-44 "Closed—Unacceptable Action" in 1999, based on the length of time that had elapsed without positive result since the recommendation was issued.

[136] National Transportation Safety Board, *Multiple-Vehicle Collision with Fire During Fog Near Milepost 118 on Interstate 40, Menifee, Arkansas, on January 9, 1995, Special Investigation of Collision Warning Technology*, Highway Accident Report NTSB/HAR-95/03 (Washington, DC: NTSB, 1995).

The Safety Board published a special investigation report concerning CWSs in 2001.[137] In it, the Safety Board asked the USDOT to

> H-01-6
>
> Complete rulemaking on adaptive cruise control and collision warning system performance standards for new commercial vehicles. At a minimum, these standards should address obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning.
>
> H-01-7
>
> After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system.

Although the recommendations were originally issued to the USDOT, further communication with the USDOT indicated that NHTSA was the most appropriate agency to implement the recommendations.

The Safety Board reiterated Safety Recommendations H-01-6 and -7 to NHTSA as a result of its investigation of a 2003 multivehicle collision at a toll plaza near Hampshire, Illinois.[138] The Board determined that the probable cause was a truck driver who was driving too fast for conditions and failed to slow for traffic. The Board concluded that the driver did not detect the slowing traffic ahead of his vehicle and that, had his vehicle been equipped with a CWS, the accident might have been prevented.

In its responses to the Safety Board concerning these recommendations, NHTSA reported that the USDOT had established the intelligent vehicle initiative and was undertaking studies to collect the field operational test data needed to establish performance standards. These studies have been completed.[139] Further, in 2005, the FMCSA published voluntary performance standards for CWSs for commercial vehicles, which address functional, data, hardware and software, driver vehicle interface, and maintenance and support requirements.[140]

The Safety Board added the prevention of rear-end collisions through the use of CWSs and ACC to its Most Wanted List of Transportation Safety Improvements in November 2007. NHTSA has been working consistently, though

[137] National Transportation Safety Board, *Vehicle- and Infrastructure-based Technology for the Prevention of Rear-End Collisions*, Special Investigation Report NTSB/SIR-01/01 (Washington, DC: NTSB, 2001).

[138] National Transportation Safety Board, *Multivehicle Collision on Interstate 90, Hampshire-Marengo Toll Plaza, Near Hampshire, Illinois, October 1, 2003*, Highway Accident Report NTSB/HAR-06/03 (Washington, DC: NTSB, 2006).

[139] Volvo (2005) and Battelle (2007).

[140] Federal Motor Carrier Safety Administration, *Concept of Operations and Voluntary Operational Requirements for Automated Cruise Control/Collision Warning Systems (ACC/CWS) On-board Commercial Motor Vehicles*, FMCSA-MCRR-05-007 (Washington, DC: FMCSA, 2005).

slowly, on this issue. It has recently published its report on the field operational test conducted by Battelle and Volvo Trucks North America, showing a reduction in rear-end crashes.[141] The Safety Board has not received any information on NHTSA's interpretation of the commercial vehicle testing or a timeline for future NHTSA actions to mandate use of this technology. Rulemaking as requested in Safety Recommendation H-01-6 is needed to ensure uniformity of system performance standards, such as obstacle detection, timing of alerts, and human factors guidelines on commercial vehicles. Safety Recommendations H-01-6 and -7 are currently classified "Open—Acceptable Response."

A CWS with active braking might have prevented or lessened the severity of the impacts in the Osseo and Lake Butler accidents. In both cases, even if the driver had not reacted to the CWS, either because he was asleep or driving while impaired from fatigue (Lake Butler) or because he did not see the object in the roadway (Osseo), a system with active braking could have stopped or slowed the vehicle before it collided with the stationary vehicle in its path. If a collision is deemed imminent, an active braking CWS does not wait for the driver to react. Braking is applied automatically in this critical situation to reduce the severity of the impending collision.

It should be noted that the Safety Board is aware of some limitations of CWS with active braking. For instance, a radar system can detect the speed differential between two moving vehicles, but it has more difficulty distinguishing a stopped object, such as debris in the road or a stalled vehicle. Industry representatives have indicated that they are cautiously moving ahead in this area of technology.

CWSs alert the driver to hazardous situations and often require the driver to take evasive action, such as hard braking or rapid steering. In the case of a CWS with active braking, application of maximum braking occurs when a collision is imminent. When evasive actions are taken either by the driver or the system (such as through active braking), the stability of the vehicle is critical, especially for commercial vehicles, because they are typically large and heavy, and have relatively high centers of gravity. Such vehicles may become unstable when hard braking is applied in slippery conditions or if the driver steers rapidly to avoid a collision. Actions taken to avoid a rear-impact collision or a collision with a fixed object may result in a directional loss of control of the vehicle or in a rollover, which could be even more hazardous than the collision the driver is attempting to avoid. Therefore, the Safety Board concludes that because commercial vehicles, which typically have high centers of gravity, are prone to become unstable when they are hard-braked or steered suddenly to avoid a collision, CWS-equipped commercial vehicles should also be equipped with an ESC system addressing both roll and directional stability.

Both active braking and ESC technologies represent opportunities for significant enhancement of CWS capabilities to prevent (or mitigate) commercial

[141] Volvo (2005) and Battelle (2007).

vehicle accidents. Therefore, the Safety Board recommends that NHTSA determine whether equipping commercial vehicles with CWSs with active braking and ESC systems will reduce commercial vehicle accidents. If these technologies are determined to be effective in reducing accidents, NHTSA should require their use on commercial vehicles. In addition, the Safety Board reiterates Safety Recommendations H-01-6 and -7 to NHTSA, which recommend that NHTSA complete rulemaking on adaptive cruise control and CWS performance standards for new commercial vehicles (H-01-6), and once the CWS standards have been developed, that NHTSA require that all new commercial vehicles be equipped with a CWS (H-01-7).

The Safety Board also asked NHTSA, the FHWA, truck and motorcoach manufacturers, and the Intelligent Transportation Society of America to develop and implement a program to inform the public and commercial drivers on the benefits, use, and effectiveness of CWSs and ACCs (Safety Recommendations H-01-9, -12, -14, and -15). NHTSA and the FHWA have indicated that they would wait until field operational tests were completed before initiating such a program.

Additionally, the Safety Board recommended that the American Trucking Associations, Inc., the Owner-Operator Independent Driver Association, and the National Private Truck Council encourage their members to obtain or provide, or both, training to those drivers who operate CWS- or ACC-equipped trucks (Safety Recommendation H-01-16). The American Trucking Associations, Inc., and the National Private Truck Council reported that they encouraged their members who use advanced technologies to see that their drivers receive training. Safety Recommendation H-01-16 is classified "Closed—Acceptable Response."

Finally, although the Safety Board is pleased that technologies such as CWSs and fatigue detection systems are being developed to prevent accidents, caution may be warranted when a vehicle is equipped with multiple systems. The multiplicity of devices may affect driver performance, and system integration should be considered. Fatigue detection systems, CWSs, ESC systems, and similar technologies might be designed by different manufacturers, but they must be capable of working together harmoniously within a vehicle.

In addition to determining how the systems will be used, where displays will be located, how much information is needed, how that information will be delivered to the driver, and what information has priority, among other factors, manufacturers must evaluate the impact of the systems on drivers. Having multiple systems in the vehicle, which give different warning signals, means that the driver must not only react to a signal but also must determine which warning is being given, decide upon an appropriate action, and take that action. Driver reaction time will probably increase as the number of signals received by the driver increases. Other considerations include ensuring that signals are distinct, so the driver interprets them correctly; dealing with possible distraction from the driving task, as the driver contemplates the signal and associated action; and determining what the driver should do if multiple signals give warnings simultaneously. The Safety Board concludes that although in-vehicle warning systems offer opportunities for positive intervention to prevent accidents, providing multiple systems may overstress the driver's response and decision-making capabilities.

The USDOT has entered into a cooperative research agreement with UMTRI to develop and test an integrated, vehicle-based crash warning system that addresses rear-end, lane change, and roadway departure crashes for light vehicles and heavy commercial trucks. It is known as the Integrated Vehicle-Based Safety Systems program. Three systems are being integrated: forward-crash warning, road-departure warning, and lane-change/merge crash warning.[142] Thus far, vehicle prototypes have been developed, driver-vehicle interfaces have been evaluated,[143] and the field operational test plan has been developed. Phase II of the program is beginning, and it will include field operational tests with 108 passenger car drivers and 15 heavy truck drivers. The passenger car field operational test will take place over 12 months, and the heavy truck field operational test will cover a 10-month period. Data will be collected on driver performance with and without warning provided by the integrated safety system.

[142] University of Michigan Transportation Research Institute, *Integrated Vehicle-Based Safety Systems (IVBSS) Phase I Interim Report*, DOT HS 810 952 (Washington, DC: UMTRI, May 2008).

[143] P. Green, J. Sullivan, O. Tsimhoni, J. Oberholtzer, M.L. Buonarosa, J. Devonshire, J. Schweitzer, E. Baragar, and J. Sayer, *Integrated Vehicle Based Safety Systems (IVBSS): Human Factors and Driver-Vehicle Interface (DVI) Summary Report*, DOT HS 810 905 (Washington, DC: USDOT, February 2008).

Conclusions

Findings

1. The weather did not cause or contribute to the accident.

2. The mechanical condition of the truck-tractor semitrailer did not contribute to its departure from the roadway and subsequent rollover or to its being struck by the motorcoach; and the condition of the motorcoach's steering, suspension, and tires did not contribute to its impact with the truck-tractor semitrailer.

3. The motorcoach driver was not impaired by alcohol or drugs at the time of the accident.

4. The emergency response was timely and adequate.

5. Although the truck driver's commercial driver's license had been administratively suspended for failure to pay a fine, he had passed the licensing exam and had received an additional 280 hours of training by the motor carrier, indicating that he had the abilities needed to drive the truck-tractor semitrailer.

6. Based on urine test results, the truck driver was not impaired by illicit drugs at the time of the accident; however, although there is no evidence that alcohol was a factor in the overturn of the truck-tractor semitrailer, specimens were collected from the truck driver too late to definitively exclude impairment due to alcohol use.

7. The evidence, including an average vehicle speed of between 66 and 70 mph, the shallow angle of the truck-tractor semitrailer's departure, and witness reports of the vehicle's weaving on the road, suggests that the truck driver allowed the vehicle to drift from the roadway, indicating that the driver was operating while fatigued.

8. The truck driver was asleep at the time of the accident because of the reduced quantity of his sleep; the reduced quality of his sleep due to alcohol consumption the previous night; and the circadian desynchronization he experienced due to his operating the truck in the early morning hours, when the body is predisposed to sleep.

9. The Midwest distribution center of Whole Foods Market, Inc., provided an adequate off-duty period for the truck driver to obtain sufficient sleep, but he did not take full advantage of this opportunity.

10. Had the truck-tractor semitrailer been equipped with technologies to detect fatigue, the systems might have prevented or mitigated the severity of the fatigue-related crash.

11. The fatigued truck driver was alerted by the audible and/or tactile signal made by traveling over the rumble strips and/or grassy slope, turned the vehicle back toward the roadway, and lost control of the truck-tractor semitrailer.

12. For fatigue management plans to be successfully implemented by motor carriers over time, Federal Motor Carrier Safety Administration oversight is needed.

13. Although fatigue educational materials are becoming more widely available through the efforts of government agencies and many motor carriers, accident evidence suggests that some commercial drivers, like the Osseo truck driver, remain unaffected by the fatigue education message.

14. The truck driver and the Midwest distribution center of Whole Foods Market, Inc., failed in their responsibilities to maintain status-of-duty records.

15. Mandating the use of electronic on-board recorders by all interstate commercial vehicle carriers would ensure the availability of valid, accurate, and secure hours-of-service data, which could result in increased compliance with hours-of-service regulations.

16. The side slopes parallel to Interstate Highway 94 where the truck left the roadway were predominantly in the recoverable category; however, the circumstances of this accident, including a fatigued driver, a grassy slope with a lower coefficient of friction than the pavement, and night-time travel, made safely returning to the roadway or traversing to the bottom of the slope and stopping very difficult.

17. Given the particular circumstances of the Osseo accident, an electronic stability control system would not have prevented the truck from overturning.

18. Although the motorcoach driver did not wear corrective lenses on the night of the accident, as required, he was otherwise qualified and fit to drive the motorcoach.

19. The darkness, the absence of lighting on the truck-tractor semitrailer, and the motorcoach driver's use of low-beam headlights made it difficult for the motorcoach driver to see the overturned truck.

20. The motorcoach driver saw the overturned truck and initiated braking prior to impact; however, even a driver with ideal vision most likely would not have been able to react to the unanticipated road hazard in time to slow the motorcoach sufficiently to alter the severity of the accident.

21. The motorcoach driver's early cataract formation most likely did not affect the outcome of this accident.

22. Although the motorcoach driver's schedule provides the possibility that his performance could have been impaired by fatigue, the visibility circumstances of the accident and the braking evidence indicate that he was awake and alert but could not see the wreckage in time to prevent the collision with the overturned truck.

23. Improper maintenance of the brake system on the part of the motor carrier Chippewa Trails, Inc., resulted in two out-of-adjustment drive axle brakes, which diminished the braking force available to slow the motorcoach, but this condition likely did not contribute to the accident.

24. A collision warning system with active braking might have prevented, or at least lessened the severity of, the motorcoach's impact with the overturned truck.

25. Because commercial vehicles, which typically have high centers of gravity, are prone to become unstable when they are hard-braked or steered suddenly to avoid a collision, collision warning system-equipped commercial vehicles should also be equipped with an electronic stability control system addressing both roll and directional stability.

26. Although in-vehicle warning systems offer opportunities for positive intervention to prevent accidents, providing multiple systems may overstress the driver's response and decision-making capabilities.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the truck-tractor semitrailer rollover, the precipitating event in the accident sequence, and the motorcoach's subsequent collision with the truck, was the truck driver's falling asleep at the wheel, drifting from the roadway, and losing control of his vehicle. The truck driver was most likely fatigued because he did not take full advantage of adequate rest opportunities provided to him during his off-duty time and, as a result, obtained inadequate and disrupted sleep prior to the accident. The motorcoach collided with the overturned truck because there were insufficient visual cues to permit the driver to identify the truck wreckage in time to avoid the collision.

RECOMMENDATIONS

New Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following safety recommendations:

To the Federal Motor Carrier Safety Administration:

> Develop and implement a plan to deploy technologies in commercial vehicles to reduce the occurrence of fatigue-related accidents. (H-08-13)
>
> Develop and use a methodology that will continually assess the effectiveness of the fatigue management plans implemented by motor carriers, including their ability to improve sleep and alertness, mitigate performance errors, and prevent incidents and accidents. (H-08-14)

To the National Highway Traffic Safety Administration:

> Determine whether equipping commercial vehicles with collision warning systems with active braking and electronic stability control systems will reduce commercial vehicle accidents. If these technologies are determined to be effective in reducing accidents, require their use on commercial vehicles. (H-08-15)

To Whole Foods Market, Inc.:

> Implement a comprehensive fatigue education program that requires company management to ensure that employees understand the risks of driving while fatigued and comply with fatigue guidelines. (H-08-16)

Reiterated Recommendations

As a result of its investigation, the National Transportation Safety Board reiterates the following safety recommendations:

To the National Highway Traffic Safety Administration:

H-01-6

Complete rulemaking on adaptive cruise control and collision warning system performance standards for new commercial vehicles. At a minimum, these standards should address obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning.

H-01-7

After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

DEBORAH A. P. HERSMAN
Member

KATHRYN O'LEARY HIGGINS
Member

ROBERT L. SUMWALT
Member

STEVEN R. CHEALANDER
Member

Adopted: September 16, 2008

Member Higgins filed the following concurring statement on September 26, 2008.

Board Member Statement

Member Kathryn O'Leary Higgins, concurring:

I believe the tragic Osseo accident is the result of a straightforward series of events: a young, relatively inexperienced truck driver, who got no more than five hours of sleep before the accident because he was socializing until 6:00 a.m., fell asleep at the wheel and overturned his tractor trailer; a bus driver traveling at an appropriate speed applied his brakes once he saw the overturned truck but was unable to stop the bus in time to avoid a tragic collision that killed the bus driver and four passengers in the bus.

I am concerned that our report focuses almost exclusively on technology for trucks and busses to prevent future accidents. While I don't oppose the use of technology when it is tested and proven, I am concerned that it will be years before we can expect to realize the results of these recommendations. We are already on record in support of electronic-on-board recorders (EOBR), for example, and the response from FMCSA has been very disappointing. We have little reason to believe that our recommendations for technologies to reduce fatigue accidents, and for collision warning and electronic stability control systems will be acted on any time soon. That doesn't mean we shouldn't pursue these recommendations, but we should not rely solely on these recommendations to address the issues in this accident. I believe there are steps that we can take that can be acted on much more quickly to address issues identified in this accident.

<u>Use of High Beams</u>

Our report indicates that the brakes on the motorcoach were not performing at full capacity because the slack adjusters had been manually adjusted. We state that the motorcoach would have needed 442 feet to come to a complete stop given the condition of the brakes. If the brakes were fully performing, the driver would have needed 278 feet. In our post-accident visibility study, we measured five approaches to the truck wreckage from a distance of 2,000 feet along a measured course with a variety of low and high beam headlight configurations. With low beams and fully functioning brakes, the driver would have needed 227 feet to recognize the hazard in the right lane and apply emergency braking to stop. With high beams, the hazard was recognized at 603.5 feet with an oncoming auto and 786.0 feet with no oncoming traffic. Witnesses indicated that there was very little oncoming traffic on the night of the accident.

With these observations, measurements and conclusions in mind, I reviewed the Wisconsin Commercial Driver's Manual (the state of the motorcoach driver's licensing and the state of the accident) for guidance on the proper use of high beam headlights. The section on night driving procedures (section 2.8, pp. 2:14-2:15) states to "use high beams when you can" and to dim high beam lights if within 500 feet of an oncoming vehicle or following another vehicle within 500 feet. This section notes that one can see 250 feet with low beams and about 250-500 feet with high beams. The manual advises that speed should be adjusted to keep stopping distance within sight distance to have sufficient time to see and avoid hazards.

Our tests show that the motorcoach driver was using his low beams. The numbers in our visibility study suggest that, if the motorcoach driver had been using high beams and reacted just as he did in all other respects, he would have increased his margin of safety and stopping distance significantly. If that is true, might the driver have avoided or significantly mitigated the impact of this accident? I am not suggesting that the motorcoach driver was in any way at fault but he was traveling on a dark, unlit section of interstate in the middle of the night with very little oncoming traffic.

The Wisconsin manual indicates that some drivers make the mistake of always using their low beams. I disagree with staff that a recommendation on high beam headlight use might encourage commercial drivers to use high beams when it is not safe to do so. The Wisconsin Commercial Driver's Manual and other guidance I've reviewed is very clear on the conditions that call for use of high beams. We place a great deal of responsibility on the shoulders of commercial drivers, and I believe, with the proper training and education, they will respond to instruction on proper high beam use in a responsible way. As we prepare articles about this accident to be included in magazines for commercial drivers, I urge staff to take this opportunity to educate drivers about the use of high beams to increase visibility at night, which will also increase the margin of safety and stopping distance if a hazard should be in the road.

Driver Fatigue

Our report discusses the initial driver training given to Whole Foods drivers and the video and materials on fatigue that are made available to them. I believe the report sufficiently establishes that this truck driver was fatigued because he did not use his off duty time to ensure that he got adequate rest before undertaking his next trip. We thus conclude that the truck driver's failure to change his behavior to ensure that he did not drive fatigued suggests that Whole Foods' fatigue education program was insufficient either in content or in application. I am pleased that we not only ask FMCSA to evaluate motor carriers fatigue management programs but we also ask Whole Foods Market, Inc. to implement a comprehensive fatigue education program that requires company management to ensure that employees understand the risks of driving while fatigued and comply with fatigue guidelines. I hope the Safety Board's planned articles for inclusion in relevant and targeted publications will educate drivers about the facts and circumstances of this classic fatigue accident.

Crashworthiness

Finally, I appreciate that staff added language to the report to address some of the issues of the crashworthiness of the motorcoach. This issue is on our Most Wanted List and is of great interest to Members of Congress and families who lost loved ones in this and other accidents, and it deserves attention in this report. Our additions to the factual section of our report briefly discuss our previous recommendations to enhance protection for motorcoach passengers and what NHTSA is doing now in response to those recommendations. We now have helped those who are keenly interested in these issues understand their significance in this accident.

Appendix A

Investigation

The National Transportation Safety Board received notification of this accident on October 16, 2005. The Safety Board launched a team of investigators with personnel from the Washington, D.C.; Arlington, Texas; and Atlanta, Georgia; offices. Groups were established to address human performance, survival factors, motor carrier, vehicle, vehicle recorder, and highway issues. No Board Member took part in the on-scene investigation.

Participating in the investigation were the Federal Motor Carrier Safety Administration; the Wisconsin State Patrol; Chippewa Trails, Inc.; Whole Foods Market, Inc.; the Wisconsin Department of Transportation; Motor Coach Industries, Inc.; Haldex Brake Products Corporation; Ryder Systems, Inc.; and Bendix.

No public hearing was held in connection with this accident.

Appendix B

Lake Butler, Florida, Accident Brief

National Transportation Safety Board
Washington, DC 20594

Highway Accident Brief

Accident Number:	HWY-06-MH-013
Accident Type:	Rear-end chain-reaction collision
Location:	State Route 121, near Lake Butler, Florida
Date and Time:	January 25, 2006, 3:25 p.m. eastern standard time
Vehicles:	1996 Thomas Built school bus 1993 Pontiac Bonneville sedan 2004 Freightliner truck tractor and 1998 Wabash box trailer
Owners/Operators:	Union County, Florida, School District Private owner Crete Carrier Corporation
Fatalities/Injuries:	7 fatalities 5 serious injuries 6 minor injuries

Accident Description

About 2:40 p.m. on Wednesday, January 25, 2006, a 31-year-old truck driver, operating a 75,360-pound 2004 Freightliner truck tractor and 1998 Wabash box trailer combination unit (Freightliner), departed High Springs, Florida, on an 85-mile trip to a company warehouse in Jacksonville, Florida. The driver was transporting a load of bottled water. Meanwhile, about 3:05 p.m., a 48-year-old school bus driver began her afternoon route in a 1996 Thomas Built school bus, Union County bus no. 13.

The northbound school bus was stopped on State Route (SR) 121 at bus stop no. 10, near 75th SW Terrace, to discharge two students. A 1993 Pontiac Bonneville—occupied by a 15-year-old driver and six passengers, ages 20 months to 15 years—was stopped behind the school bus. As the school bus was beginning to proceed, the Freightliner collided with the rear of the Pontiac and the bus. Police estimated the speed of the Freightliner to be 62 mph.

The Freightliner and the Pontiac continued forward from the impact area, departing the travel lanes to the right. The Freightliner then traveled 260 feet and collided with a 21-inch-diameter pine tree. The Pontiac was pushed 272 feet to its final position, where it was destroyed in a postcrash fire. The school bus was pushed a distance of 328 feet and came to rest on the right side of the road. Both the Freightliner and the school bus sustained extensive impact damage.

All seven occupants of the Pontiac were killed. Three of the nine students on the school bus were ejected from the rear of the vehicle and landed on highway pavement, seriously injured. One other student sustained serious injuries and was extricated from the bus by firefighters. The school bus driver, who was wearing a lap shoulder belt, also sustained serious injuries. Five students and the truck driver received minor injuries. The students who had been discharged from the bus just before the accident were not injured. Figure 1 shows the seating chart for the school bus, and table 1 provides injury information.

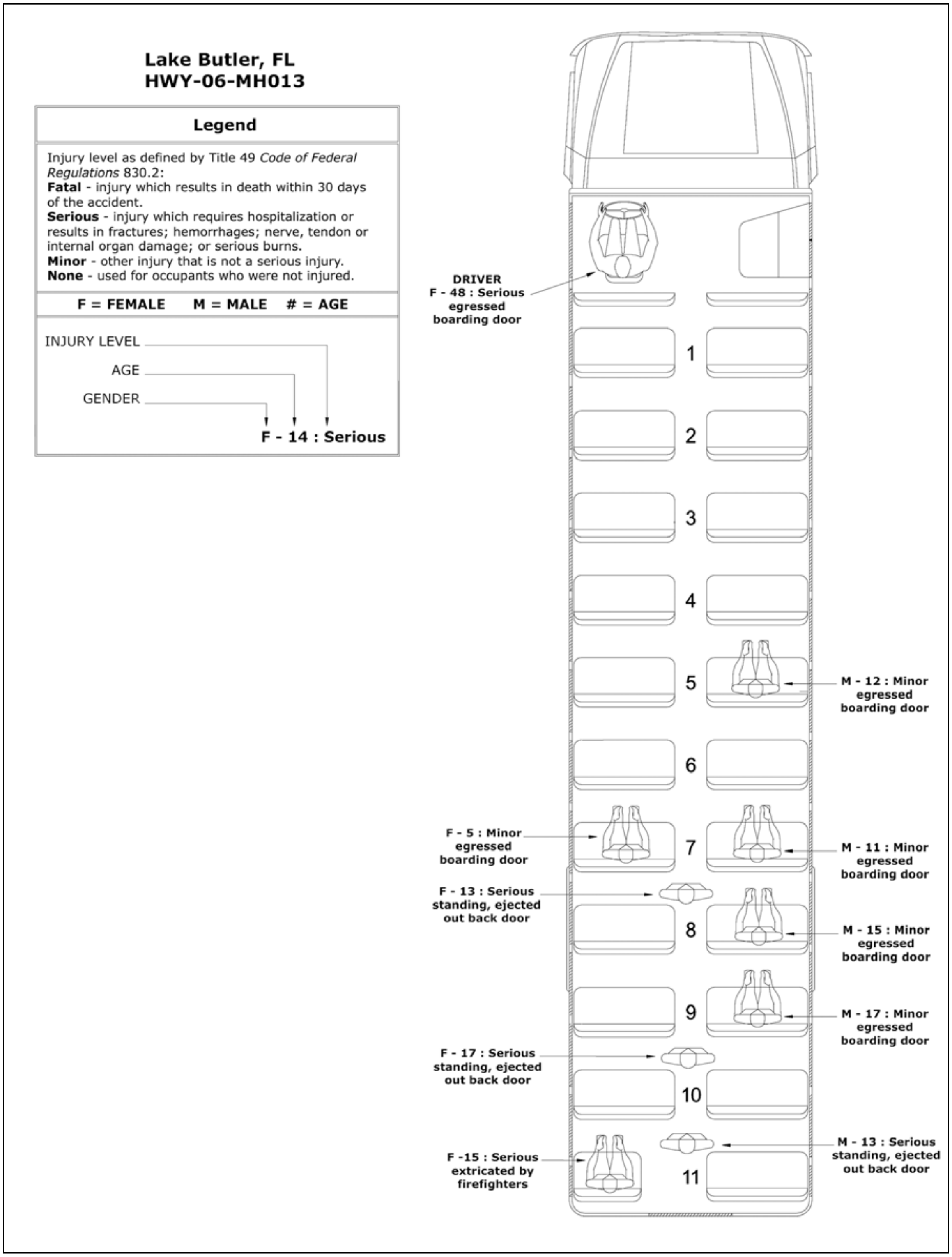

Figure 1. Seating chart, Union County school bus.

Table 1. Injuries

Injury[A]	School bus driver	School bus passengers	Pontiac occupants	Truck driver	Total
Fatal	0	0	7	0	7
Serious	1	4	0	0	5
Minor	0	5	0	1	6
None	0	0	0	0	0
Total	1	9	7	1	18

[A]Title 49 *Code of Federal Regulations* (CFR) 830.2 defines fatal injury as any injury that results in death within 30 days of the accident. It defines serious injury as any injury that requires hospitalization for more than 48 hours, commencing within 7 days of the date of injury; results in a fracture of any bone (except simple fractures of the fingers, toes, or nose); causes severe hemorrhages, or nerve, muscle, or tendon damage; involves any internal organ; or involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

Highway

The accident occurred on SR 121 at milepost 5.4. The Florida Department of Transportation (FDOT) classifies SR 121 as a rural minor arterial roadway.[1] According to FDOT, the average daily traffic on this roadway in 2004 in the vicinity of the accident was 6,100 vehicles, with buses accounting for 1 percent and trucks accounting for 22 percent of the total vehicular traffic.

At the accident location, SR 121 is a two-lane undivided asphalt roadway running north-south. The paved area consists of two 12-foot-wide main travel lanes, marked by solid 6-inch white lines, with a 5-foot-wide shoulder on either side. The paved shoulders border 3-foot-wide grass areas. A 6-inch yellow dashed centerline separates the northbound and southbound lanes. The speed limit was 60 mph, and speed limit signs were located 2.7 miles prior to the accident scene.[2] Figure 2 presents a view of SR 121 northbound, 375 feet prior to the accident location.

[1] American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets*, fifth edition (Washington, DC: AASHTO, 2004) 9. AASHTO classifies a rural minor arterial roadway as follows: "The rural minor arterial road system, in conjunction with the rural principal arterial system, forms a network with the following service characteristics: 1. Linkage of cities, larger towns, and other traffic generators (such as major resort areas) that are capable of attracting travel over similarly long distances. 2. Integrated interstate and intercounty service. 3. Internal spacing consistent with population density, so that all developed areas of the state are within reasonable distances of arterial highways. 4. Corridor movements consistent with items (1) through (3) with trip lengths and travel densities greater than those predominantly served by rural collector or local systems."

[2] A speed study conducted by Safety Board investigators on January 30, 2006, from 3:00–4:00 p.m., in the northbound lanes of SR 121, showed the 85th percentile speed as 65 mph.

Figure 2. SR 121 approaching accident location.

The 2003 *Manual on Uniform Traffic Control Devices* (MUTCD) recommends that *School Bus Stop Ahead* signs be installed in advance of school bus stops where the bus is not visible to road users for a distance of 500 feet.[3] FDOT provides similar guidance.[4] No school bus signs were located in the vicinity of the accident. The Safety Board conducted a sight distance test on January 31 and February 1, 2006, assisted by the Florida Highway Patrol, which showed that the school bus was visible for a distance of 3,087 feet, far above the recommended 500-foot distance. The alternating red warning lights on the rear of the school bus were visible at 1,382 feet. A regulatory sign stating *All Traffic Both Directions STOP While School Buses Load or Unload* was located about 4 miles in advance of the accident site.

Vehicles

School Bus

The accident bus was a 65-passenger school bus manufactured in 1996 by Thomas Built Buses, Inc. The bus weighed 17,250 pounds and had a body length of 417.9 inches.

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[3] U.S. Department of Transportation, Federal Highway Administration, *Manual on Uniform Traffic Control Devices for Streets and Highways*, Part 7, Traffic Controls for School Areas (Washington, DC: FHWA, 2003) 7B-3.

[4] Florida Department of Transportation, *Design Standards, School Signs, and Markings*, Sheet No. 4 of 6, Index No. 17344 (Tallahassee, FL: FDOT, 2006).

The bus sustained the majority of damage at the rear end, where it was struck by the Freightliner. The rear of the bus was pushed inward just left of center, which affected the entire rear surface area of the bus, to just below roof level. (See figure 3.) The maximum point of inward intrusion was about 5 feet. The entire bus body was deformed from the rear-end damage, and the driver's seat was sheared off its pedestal mounting.

The tires on the bus met recommended manufacturer specifications and were in good condition. The steering and the suspension systems appeared to be normal. The brake on the left front axle was found to be out of adjustment and would have resulted in the bus being out of service according to the Commercial Vehicle Safety Alliance North American Standard Out-of-Service Criteria. However, the bus was nearly stopped at the time of the accident, and the braking system was not causal to the accident.

Figure 3. Accident school bus.

Statements from the bus driver, passengers, and a witness driving in the opposite direction indicated that the bus warning lights and strobe light were activated while the bus was stopped and discharging passengers. Statements from the bus driver and passengers also indicated that, at the time of impact, the school bus door was closed, the warning lights were turned off, and the bus was beginning to move forward. The Safety Board laboratory examination of the lights revealed that none of the filaments contained hot stretching damage.[5]

Passenger Car

The passenger car involved in the accident was a 1993 Pontiac Bonneville. The sedan had a precrash curb weight of 3,355 pounds, a length of 200.9 inches, a width of 73.7 inches, and an overall height of 55.6 inches.

The vehicle was extensively damaged by the impact of the Freightliner and the postcrash fire, which consumed most of its nonmetal components. (See figure 4.) The Florida State Fire Marshal determined that the origin of the fire was the fuel tank located at the rear of the vehicle; the tank was found to have been breached as a result of the crash and to have come into contact with the pavement, introducing an ignition source. The fuel tank had a small tear from being ground into the pavement.

Figure 4. Remains of accident passenger car.

Tractor-Trailer Combination Unit

The accident truck tractor was a 2004 Freightliner, and the trailer was a 1998 Wabash box trailer that was 53 feet long, 13.5 feet tall, and 8.5 feet wide. The total weight of the truck tractor-trailer combination unit was estimated to be 75,360 pounds.

[5] The Safety Board examined the warning lights in the dash; the top-rear, bottom-rear, top-front, and bottom-front stop sign light bulbs; and the left-rear, middle-rear, right-rear, left-side, and right-side clearance lights.

The tractor and the front of the trailer, shown in figures 5 and 6, sustained the majority of the damage. The cab portion of the tractor was completely detached and separated from the tractor chassis.

Figure 5. Cab portion of accident tractor.

The tires on the tractor were slightly narrower than the width recommended by the tractor specifications.[6] However, this discrepancy would not have affected the rolling radius or vehicle handling. Damage to the steering and suspension systems appeared to be a direct result of the accident. The brakes of the tractor and trailer were found to be in adjustment and in good condition.

The tractor was equipped with a Detroit Diesel model DDEC-V electronic engine control module (ECM). Although the ECM data were analyzed, no precrash data associated with the accident were identified. This ECM was not designed or intended to function as an event data recording device.

[6] The 275/80R22.5-size tires on the tractor were just under 1 inch narrower than the 295/80R22.5-size tires recommended in the tractor specifications.

Figure 6. Front of accident box trailer.

Motor Carriers

Union County School District

The Union County School District—which covers about 80 square miles with 21 bus routes—has one elementary school, one middle school, and one high school. The school bus fleet consisted of twenty 65-passenger buses, three 71-passenger buses, one 47-passenger bus, and two special needs buses. At the time of the accident, the school district employed 19 full-time drivers, 4 substitute drivers, 2 full-time mechanics, and a transportation specialist who also did mechanical work.

Crete Carrier Corporation

Operating since 1966, Crete Carrier Corporation is an interstate, authorized for-hire carrier of general freight, building materials, and produce.[7] At the time of the accident, Crete employed 4,823 company drivers and 391 owner/operators. Of the company drivers, 202 are team drivers; and of the owner/operators, 44 are team drivers. Sixty-eight of the Crete drivers operate in intrastate commerce only. Crete's fleet includes 5,170 truck tractors and 12,482 semitrailers. In 2005, Crete's fleet traveled a total of 635.8 million miles.

[7] Dba Crete Carrier Corp Shaffer Trucking HTL Truck Line.

Roadside inspections for the 12 months prior to the accident indicate that 3,808 Crete vehicles were inspected, and 447 were placed out of service (12 percent). Additionally, of 6,157 driver inspections, 145 drivers were placed out of service (2 percent).[8] The accident rate[9] for Crete was 0.64 per million miles traveled.

A postcrash compliance review conducted by the Federal Motor Carrier Safety Administration (FMCSA) on March 15, 2006, resulted in a proposed conditional rating, but because of a consent agreement, the rating remained "satisfactory." In response to the compliance review, Crete developed a safety management plan, signed a consent agreement with the FMCSA to settle all assessed fines, and agreed to three progress reviews over the following 18 months.[10] The most recent compliance review, and the last of the three required progress reviews, was conducted on May 25, 2007, and Crete received a satisfactory rating. The last time Crete had been subjected to an FMCSA compliance review was 10 years prior to the accident, on December 7, 1995.

Driver Information

Bus Driver

The 48-year-old school bus driver possessed a valid Florida class B commercial driver's license (CDL) with no restrictions and a passenger bus endorsement. The license was originally issued on September 26, 1997. The driver had no record of traffic violations since January 2000.

Automobile Driver

The driver of the Pontiac Bonneville was a 15-year-old high school student. She held a valid Florida class E learner's permit and had no record of traffic violations. However, at the time of the accident, she was operating without a qualified driver in violation of Florida law.

Truck Driver

The 31-year-old truck driver possessed a valid Florida class A CDL, originally issued in December 2003, with no restrictions and a hazardous materials endorsement. His Florida driving record showed no traffic violations since

[8] The national out-of-service rate for fiscal year (FY) 2006 was 7.0 percent for truck drivers and 23.7 percent for trucks. In FY 2007, the national out-of-service rate was 6.8 percent for truck drivers and 22.4 percent for trucks. See <http://www.fmcsa.dot.gov/facts-research/art-safety-progress-report.htm>.

[9] Accident rate is defined as the number of recordable accidents per million miles traveled. The FMCSA has determined that motor carriers with an accident rate of 1.5 or greater are deficient in the accident area of the compliance review rating process.

[10] If improvements were not achieved during the 18-month period, the safety rating would have reverted to conditional.

October 2001. He had 2 years of truck driving experience, including 10 months driving with Crete (since March 2005) as a company driver. The driver had a valid medical certificate and was in good general health. No ethyl alcohol or drugs were detected in the toxicological sample obtained from the truck driver by the Florida Department of Law Enforcement.

Data from the DDEC indicated that—in the 72 hours prior to the accident—the truck had been driven a total of 24 hours 57 minutes and had idled for 8 hours 38 minutes. The truck driver, through his lawyer, declined to be interviewed by Safety Board investigators. The following summary of his work–rest history is based on the truck driver's statement taken on May 7, 2008.[11] Qualcomm[12] data supported his statement. He had been driving a regular route between Jacksonville and High Springs, Florida, for about 2 months prior to the accident. A round trip took about 5 hours—2 hours from Jacksonville to High Springs, 30–60 minutes loading or switching trailers, and 2 hours for the return trip.

On Saturday, January 21, the truck driver began driving at 1:27 p.m. and continued until 6:30 p.m. The following day, Sunday, he worked from 12:42 p.m. until 6:00 p.m. He was off duty until 6:29 a.m. on Monday, January 23, and worked until 8:23 p.m. that evening, a total of 14 hours. On Tuesday, January 24, he began driving at 5:19 a.m., making two round trips from Jacksonville to High Springs and a half trip back to High Springs shortly after midnight on January 25. The driver said he slept in the sleeper berth for a couple of hours while the truck was being loaded in High Springs. Then he made the return trip to Jacksonville. The driver said he "rested his head across the steering wheel" for an hour or two when he returned to Jacksonville. He made another trip to High Springs on the morning of January 25 and was on his way back to Jacksonville when the accident occurred, at 3:25 p.m. (See figure 7.)

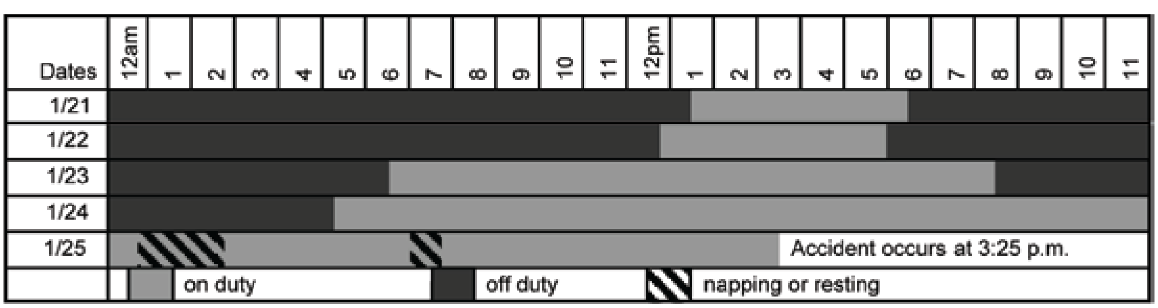

Figure 7. Duty status of Freightliner driver, January 21–25, 2006.

[11] *State of Florida v. Alvin E. Wilkerson*, Examination Under Oath Taken by Plaintiff, May 7, 2008, at Alachua County State Attorney's Office, case no. 63-2006-CF-000204-A.

[12] The Qualcomm Qtracs system uses a transmitter/receiver that allows objects to be continually tracked through global positioning satellites. The system identifies the location of each truck every hour, as well as the corresponding time and date and whether the truck engine is running.

Prior to the accident, the last period of time the driver had to obtain significant sleep was when he was off duty from 8:23 p.m. on January 23 until 5:19 a.m. on January 24, nearly 9 hours. With the exception of a 2-hour sleep period on the morning of January 25 and 1–2 hours of rest a few hours later, around 7:00 a.m., the truck driver was awake for about 30 hours, and it had been 34 hours since his last substantial off-duty period. The DDEC showed that the truck had been driven a total of 13.5 hours and idled for 4 hours 13 minutes during this period.

The reduced quantity and quality of sleep would have made the truck driver susceptible to fatigue and impaired performance. Research has shown that—in spite of individual variations—a specific amount of uninterrupted sleep is necessary for each 24-hour period, usually about 8 hours, and subsequent alertness will be compromised without that sleep.[13] Additionally, sleeping less than 4 consolidated hours can impair performance for tasks that require vigilance.[14] Fatigue impairs information processing and reaction times, increasing the probability of errors.[15]

Because of the body's natural circadian rhythms, there are two periods of maximal sleepiness in a 24-hour day—one roughly between 3:00–5:00 a.m. and a second, less pronounced period, from 3:00–5:00 p.m. The Lake Butler accident occurred about 3:25 p.m., a time when the driver may have been predisposed to sleepiness, particularly after being awake for approximately 34 hours with short periods of time as the only opportunities for sleep.

FDOT determined that the accident truck driver was classified as an interstate operator because he had traveled outside the State of Florida to Georgia in November 2005 and to Arizona, California, Mississippi, Nevada, South Carolina, Tennessee, Texas, and Utah in October 2005. Because the driver had operated in interstate commerce, he was considered to be an interstate operator and subject to the Federal hours-of-service regulations.

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[13] (a) Mary A. Carskadon and William C. Dement, "Normal Human Sleep: An Overview," *Principles and Practice of Sleep Medicine*, second edition, eds., M. Kryger, T. Roth, and W.C. Dement (Philadelphia, PA: W. B. Sanders Company, 1994) 16–26. (b) Thomas Roth, Timothy A. Roehrs, Mary A. Carskadon, and William C. Dement, "Daytime Sleepiness and Alertness," *Principles and Practice of Sleep Medicine*.

[14] P. Naitoh, "Minimal Sleep to Maintain Performance: the Search for Sleep Quantum in Sustained Operations," *Why We Nap: Evolution, Chronobiology and Functions of Polyphasic and Ultrashort Sleep*, ed., C. Stampi (Boston, MA: Birkhauser, 1992) 199–216.

[15] (a) D.F. Dinges, "The Nature of Sleepiness: Causes, Context, and Consequences," *Perspectives in Behavioral Medicine: Eating, Sleeping, and Sex*, eds., A. Stunkard and A. Baum (Hillsdale, NJ: Lawrence Erlbaum, 1989) 147–179. (b) D.F. Dinges, "Probing the Limits of Functional Capability: the Effects of Sleep Loss on Short-Duration Tasks," *Sleep, Arousal and Performance: Problems and Promises*, eds., R.J. Broughton and R. Ogilvie (Boston, MA: Birkauser-Boston, Inc., 1992).

As codified in 49 CFR 395, Federal hours-of-service regulations permit a person to drive for 11 hours following 10 consecutive hours off duty. Additionally, a person cannot drive beyond the 14^{th} hour after coming on duty following 10 consecutive hours off duty. The 60/70-hour rule states that a person cannot drive after having been on duty 60 hours in 7 consecutive days or 70 hours in 8 consecutive days. The accident driver was in violation of the regulations for driving and being on duty without receiving 10 consecutive hours off duty and also in violation of the 60/70-hour rule for having been on duty more than the permitted time.

The U.S. Department of Transportation defines a driver as operating in interstate or intrastate commerce based on the particular load origination and destination at the time of shipment. Consequently, the FMCSA classified this driver and this shipment as an intrastate operation not subject to Federal hours-of-service regulations.

At the time of the accident, Florida permitted a driver in intrastate commerce to drive for 15 hours in a 24-hour period, following 8 hours off duty, if the driving was done within a 200-mile radius. Additionally, a driver could not drive over 72 hours in 7 days or 84 hours in 8 days. The Qualcomm data for the Freightliner indicate a loss of signal for about 9 hours, from 8:23 p.m. on January 23 until 5:19 a.m. on January 24. The driver was on duty from 5:19 a.m. that morning until the accident occurred at 3:25 p.m. the following day, January 25, approximately 34 hours. The driver did not receive an additional 8-hour off-duty period within 24 hours, placing him in violation of Florida regulations.

Florida revised its hours-of-service regulations for intrastate commerce on October 1, 2006. The maximum 24-hour driving time was reduced to 12 hours following 10 consecutive hours off duty and no more than 70 hours in 7 days or 80 hours in 8 days. The accident driver would not have been in compliance with these revised State regulations.

In total, the accident driver made three and a half round trips between Jacksonville and High Springs, Florida, from January 24–25. Had he not been involved in the accident, he would have completed four round trips. Even with only three round trips between Jacksonville and High Springs, it would have been very difficult to remain in compliance with the hours-of-service regulations. Qualcomm communication data show that the driver was asked to make three round trips on this route or at least two and a half runs, thus pressuring the driver to the outer limits of the State regulation. Furthermore, the Qualcomm data show the location of the truck and should have alerted Crete that the driver was making more trips than would have been allowable.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the truck driver to maintain alertness due to fatigue from obtaining inadequate rest. Contributing to the accident was the failure of Crete Carrier Corporation to exercise proper oversight of the driver's hours of service.

Adopted: August 22, 2008

APPENDIX C

Turrell, Arkansas, Accident Brief

National Transportation Safety Board
Washington, DC 20594

Highway Accident Brief

Accident Number:	HWY-05-MH-006
Accident Type:	Motorcoach run-off-the-road and rollover
Location:	Interstate 55, near Turrell, Arkansas
Date and Time:	October 9, 2004, 5:02 a.m.
Vehicles:	1988 Motor Coach Industries, Inc., 47-passenger motorcoach
Owners/Operators:	Walters Bus Service, Inc.
Fatalities/Injuries:	15 fatalities 13 serious injuries 2 minor injuries

Accident Description

On October 9, 2004, about 5:02 a.m., a 1988 Motor Coach Industries, Inc. (MCI), 47-passenger motorcoach was southbound on Interstate 55 (I-55) near Turrell, Arkansas, transporting 29 passengers to a casino in Tunica, Mississippi. Witnesses following the motorcoach prior to the accident estimated that it had been traveling about 70 mph. At the exit 23A interchange, the motorcoach veered to the right and entered the grassy area between the exit ramp and the entrance ramp. (See figure 1.) As it rotated in a clockwise direction, the motorcoach struck an exit sign, overturning onto its left side and sliding in a southwesterly direction. The left side of the vehicle struck the westernmost side of a 2-foot-deep earthen drainage ditch, and the motorcoach continued to roll over. As it rolled, the roof opened up, allowing passengers to be thrown from the open top. The motorcoach landed 65 feet from the drainage ditch and came to rest upside down. Its roof was laying on the ground (top side up), still hinged to the right side of the vehicle.

Figure 1. Path of motorcoach from I-55. (Courtesy of Arkansas Highway Police)

At the time of the accident, it was dark and there was no highway safety lighting. The roadway was wet from a misting rain, but there was no standing water.

Survival Aspects

The motorcoach driver was not wearing his lap belt, and the passenger seats were not equipped with seat belts. The rollover and partial detachment of the roof resulted in the ejection of all 30 occupants. Of the six passengers trapped under the roof, five were fatally injured, and one sustained serious injuries. One of the three passengers found under the motorcoach body survived. In total, 14 passengers and the driver, who was partially trapped under the roof, were killed; 13 passengers were seriously injured, and 2 received minor injuries. (For fatality and injury information, see table 1.)

Table 1. Injuries.

Injury[A]	Motorcoach driver	Motorcoach passengers	Total
Fatal	1	14	15
Serious	0	13	13
Minor	0	2	2
None	0	0	0
Total	1	29	30

[A]Title 49 *Code of Federal Regulations* (CFR) 830.2 defines fatal injury as any injury that results in death within 30 days of the accident. It defines serious injury as any injury that requires hospitalization for more than 48 hours, commencing within 7 days of the date of injury; results in a fracture of any bone (except simple fractures of the fingers, toes, or nose); causes severe hemorrhages, or nerve, muscle, or tendon damage; involves any internal organ; or involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

The Crittenden County Sheriff's Department Communications Center served as the primary public safety communications center, with the West Memphis Fire Department providing support. Four police agencies, 3 local fire departments, and 18 ambulances (12 were used) responded to the accident.[1] The Crittenden County Sheriff's Department was notified of the accident at 5:04 a.m. and immediately dispatched two deputies, who arrived on scene at 5:12 a.m. with a Crittenden County Game and Fish Conservation officer. The first ambulance from the Crittenden County Ambulance Service was dispatched at 5:13 a.m. and arrived at 5:25 a.m. The West Memphis Fire Department was dispatched at 5:18 a.m. and arrived at 5:35 a.m.

Three months after the accident, a Safety Board investigator met with staff from the Crittenden County Sheriff's Department to review its role in the accident and to examine the related policies and operation of the communications center. On February 22, 2005, Safety Board investigators identified several deficiencies and organizational failures concerning the emergency response to the accident. On April 5, 2005, the Crittenden County sheriff outlined the progress that had been made in improving the emergency response system.

Vehicle

The vehicle involved in the accident was a 1988 MCI 47-passenger motorcoach, model 96-A3. The bus was 11 feet high, 8 feet wide, and 40 feet long. The empty gross vehicle weight was 28,200 pounds. The motorcoach was not equipped with an electronic data recorder.

[1] Crittenden County Sheriff's Department, Crittenden County Game and Fish Conservation Office, Arkansas State Police, Marion Volunteer Fire Department, West Memphis Fire Department, and Earle Fire Department.

The motorcoach was equipped with power steering and a TRW/Ross model HFB-70054 integral[2] steering gearbox, which were found to be functional. The vehicle's standard dual circuit air brake system with S-cam drum brakes was in good working condition. All brakes were in adjustment according to standards used by the Commercial Vehicle Safety Alliance. The 2L-outside tire had only 47 psi—rather than the normal full pressure of 95 psi—but was found with grass lodged around the tire and the rim, which most likely occurred during the rollover sequence and resulted in air escaping the tire. The left tag axle tire was bald, and the right-side tire was bald in spots and had a 1/32-inch tread depth. The tread depths of the remaining tires met Federal regulations of 4/32 inch for the steer axle and 2/32 inch for all other tires, as required by 49 CFR 393.75 and 49 CFR appendix G, subchapter B. The air suspension system included eight air bags in good working condition.

The motorcoach body sustained damage to the upper-front driver's side corner, right-passenger-side rear corner near the lavatory, and roof. (See figure 2.) During the rollover, the entire left side of the roof, including the front and rear upper structures, became separated from the motorcoach sidewall at the sash rail (lower window sill level). At final rest, the motorcoach was upside down with the roof adjacent to the body (top side up) and still partially attached along the right side by several vertical posts.[3] The motorcoach sustained significant interior damage as a result of the rollover.

During the investigation, it was discovered that—2 years prior to the accident—the motorcoach had sustained fire damage to its roof and interior as a result of a fire in a facility in which it was parked. Postcrash inspection revealed 14 additional panels of sheet metal attached on top of the original 14 panels on both sides of the roof along its curvature.[4] (See figure 3.) The new roof panels were 35 by 60 inches. The panels were glued and riveted using Magna-Lock rivets on top of the original roof panels, which ran horizontally from window line to window line and measured 106.25 inches in length and 62 inches in width. Rivet holes drilled to attach the new roof panels were misaligned with the original rivet holes. The investigation also revealed corrosion of several roof vertical posts, roof rails, roof bows, and sash rails along both sides of the motorcoach. Stick welding (oxyacetylene) found in the right-rear upper structure of the roof was also indicative of previous repairs.

[2] "Integral" refers to the manual steering gear, the hydraulic control valve, and the hydraulic power cylinder all being contained within the steering gearbox.

[3] The roof vertical posts were cut by rescue personnel.

[4] A Safety Board metallurgist, along with the MCI director of engineering, inspected the motorcoach roof at the Safety Board's materials laboratory on October 19–20, 2004.

Figure 2. Motorcoach postaccident, with roof detached.

Figure 3. Roof of motorcoach, postaccident.

Although the Inter-Industry Conference on Auto Collision Repair and the National Institute for Automotive Service Excellence have uniform procedures for automobile and light truck roof repair, there are no set standards for buses. Likewise, bus manufacturers and bus repair facilities have no set standards or best practices for repairing motorcoaches. MCI said that this type of repair is not what it would have recommended, though it has no written repair procedures.

There are no roof crush or rollover standards for motorcoaches; however, the Safety Board has recommended that the National Highway Traffic Safety Administration develop performance standards for motorcoach roof strength (Safety Recommendation H-99-50) and then require newly manufactured motorcoaches to meet the standards (Safety Recommendation H-99-51). Both of these recommendations are currently classified "Open—Acceptable Response."

Highway

The accident occurred in the southbound lanes of I-55, which is a divided four-lane paved asphalt controlled access highway. The two southbound lanes measured 24 feet across and were constructed with paved shoulders. The left shoulder was 4 feet wide, and the right shoulder was 10 feet wide. The traffic lanes had a 2-percent cross slope, and the shoulders incorporated a cross slope of about 4 percent. The northbound lanes were similarly configured and were separated from the southbound lanes by a 40-foot depressed earthen median.[5] Except for a 1-degree right-hand curve, the southbound approach to the accident location consisted of a tangent section of comparatively flat roadway.

The traffic lanes were divided by 4-inch-wide diamond-patterned retroreflective thermoplastic white lines approximately 10 feet in length and spaced 30 feet apart. The left lane was separated from the shoulder by a 4-inch-wide profiled[6] yellow edge line, while the right lane was separated from the shoulder by a combination of a 4-inch-wide profiled and a 7-inch-wide smooth white edge line. Sixteen-inch-wide milled rumble strips were installed on the left and right shoulders about 5 inches from the edge line. In addition to the thermoplastic lane markings, lanes were further delineated by retroreflectorized pavement markers spaced about 81 feet apart. These markers were also incorporated at the gore areas between the traffic lane and exit ramps, where they were spaced every 10 feet and placed adjacent to the edge lines of both the main travel lane and the exit ramp.

[5] The width of the center median, including both shoulders, was determined by measuring the distance between the yellow edge lines of the left shoulders, northbound and southbound.

[6] The thermoplastic material was embossed with a continuous series of perpendicular ribs. This material was first used by the Arkansas State Highway and Transportation Department in 1994 on an all-weather pavement marking demonstration project. It has been used regularly by the State since 1997 as a means of increasing edge line retroreflectivity on wet pavement during nighttime hours.

Semirigid roadside barriers were used along the southbound approach to shield errant traffic from bridge structures and other fixtures adjacent to the roadway. The center median did not include the use of a barrier, nor was one warranted by guidelines of the American Association of State Highway and Transportation Officials. However, in addition to the roadside barriers, a nondirective crash cushion system—consisting of sand-filled plastic modules—was positioned in the center median to shield the bridge columns.

The exit 23A interchange, the scene of the accident, is a four-leg partial cloverleaf, incorporating two looped ramps in diagonally opposite quadrants. (See figure 4.) Entrance and exit maneuvers are restricted to the right side of I-55. Southbound motorists approaching the interchange encounter a diagonal exit ramp before the crossroad's overpass. A looped exit ramp is located on the other side of the overpass, and a diagonal entrance ramp is located beyond the first two exit ramps.

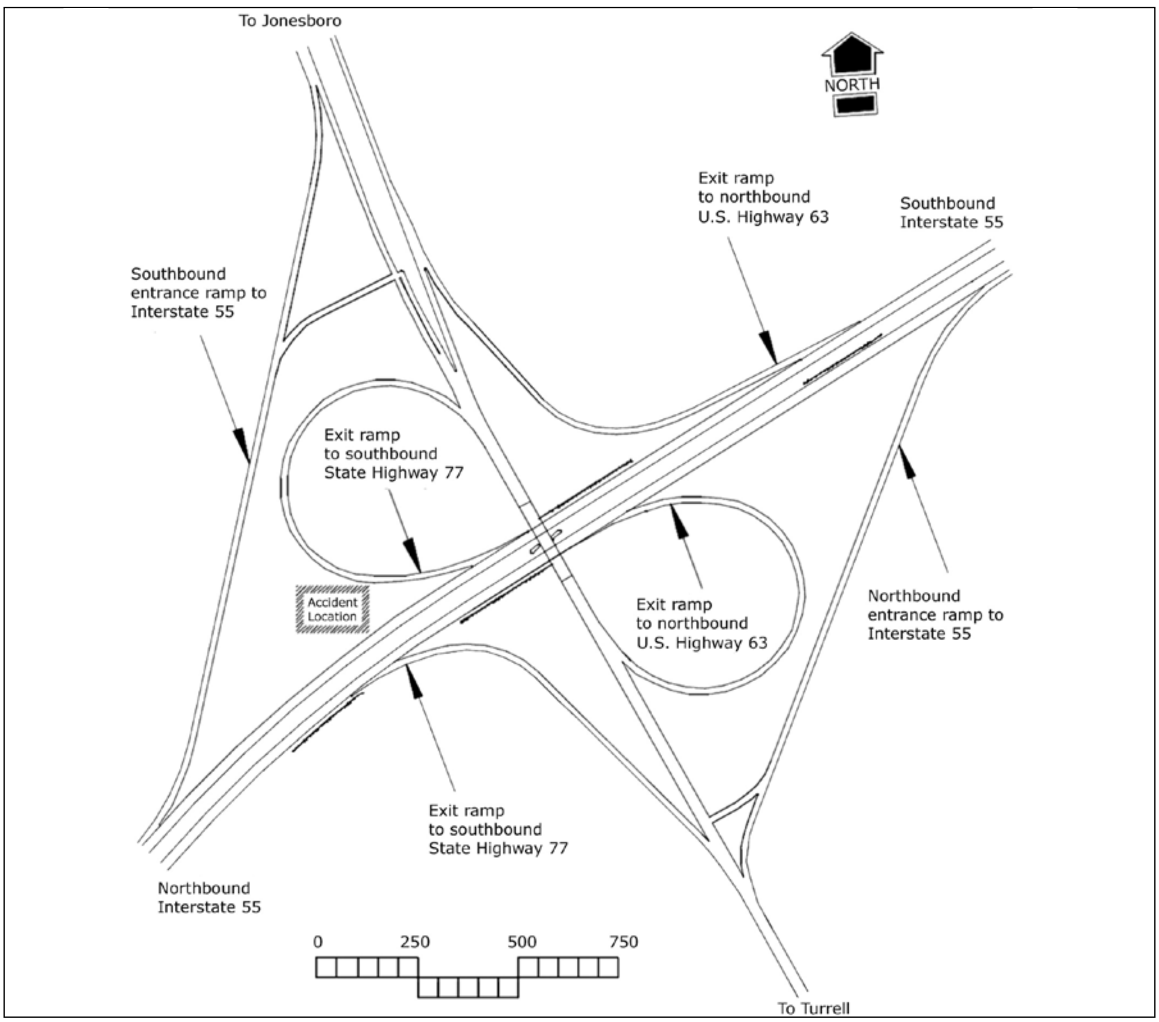

Figure 4. Layout of I-55 accident interchange.

Physical Evidence

Four tire marks about 71 feet long were located along the southbound shoulder adjacent to the right traffic lane. These marks ended at the edge of the pavement, where furrow marks continued for a distance of 55 feet to the exit 23A sign. Contact damage was observed along the right edge of the exit sign panel, 9 feet above the ground. (See figure 5.) Another tire mark—beginning about 41 feet south of the origin of the four tire marks—was observed along the left side of the exit ramp.

Figure 5. Gore area with furrow marks.

The furrow marks continued for an additional 97 feet until they went across a pair of posts supporting a right arrow sign. The accident motorcoach had overrun the sign, bent the posts forward until they became detached, and then traversed a drainage ditch, leaving a 6- by 8-foot scar. A debris field extended across both sides of the drainage ditch. The motorcoach came to rest about 65 feet south of the ditch. (See figure 6.)

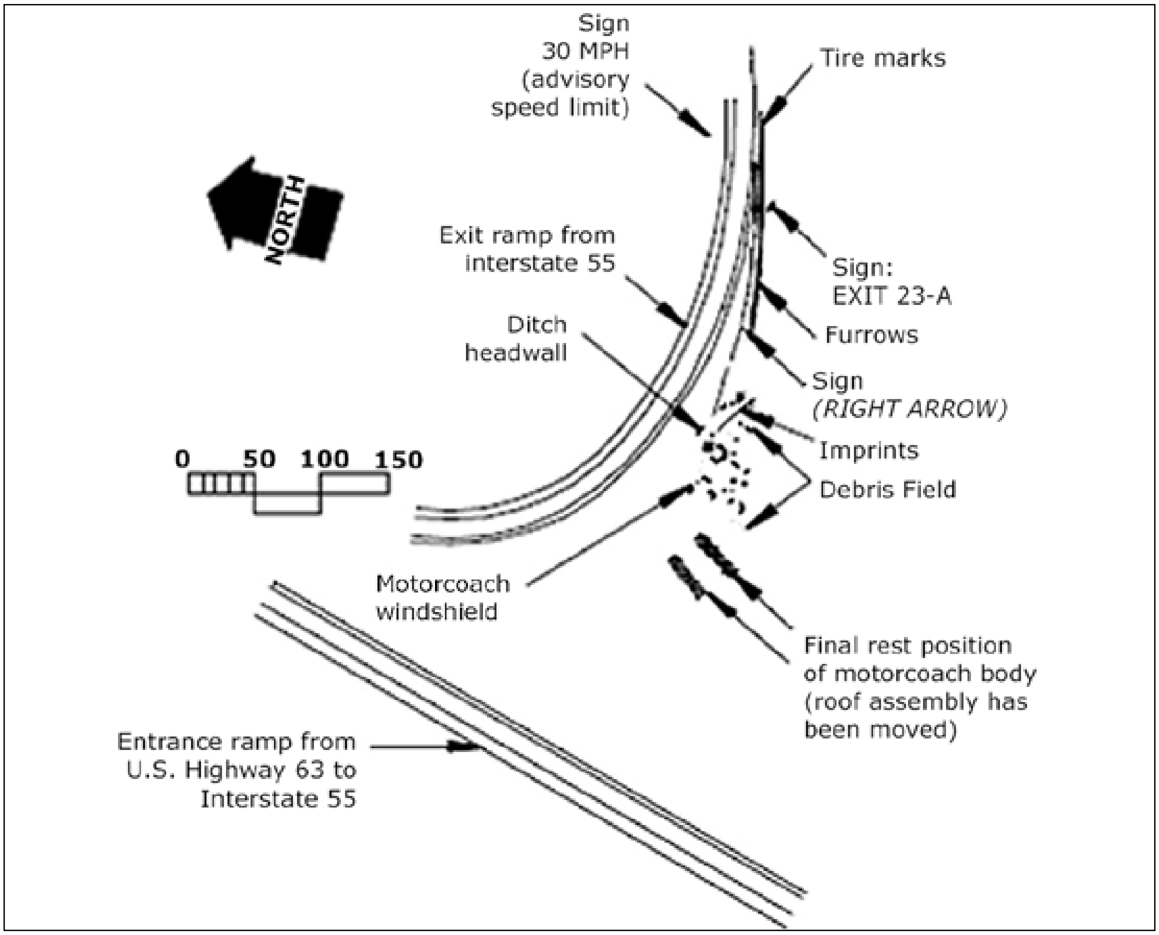

Figure 6. Accident scene diagram.

Accident Reconstruction

The precrash lane position of the motorcoach was unknown because no pavement evidence was found on the main travel lanes of the interstate, and the passengers were asleep prior to the accident event. However, analysis of the vehicle's approach based on the tire marks and furrow marks suggests that, prior to leaving the roadway, the motorcoach had been traveling in the left southbound lane. Possible interaction with the rumble strips was also considered when determining the precrash lane position. Evidence indicated that the motorcoach traveled in a curved path and, based on the degree of curvature, the vehicle would have just come into contact with the rumble strips and then started a directional change to the right. The motorcoach departed the road at an 11-degree angle. As the vehicle continued forward and over the right arrow sign, it began to roll longitudinally onto its left side. At final rest, the motorcoach had rotated about 540 degrees, or about one and one-half times over.

Motor Carrier

Walters Bus Service, Inc. (Walters), was an interstate "for-hire" carrier of passengers. Walters operated one motorcoach and had one driver. Annual mileage reported for 2002 was 30,000 miles. The company operated passenger charter tours throughout the continental United States as well as shuttle service for events in the Chicago and Detroit areas. At the time of the accident, Walters had had no reported driver or vehicle inspections or reportable accidents in the 30 previous months for which data were available.

Walters was rated "satisfactory" on October 15, 1987, following its only Federal Motor Carrier Safety Administration compliance review in 19 years of operation. A postaccident compliance review resulted in an unsatisfactory rating. Walters was found to be noncompliant with requirements for drug/alcohol random testing, driver qualification files, driver logs, maintenance and inspection programs, and periodic inspection of commercial motor vehicles. Walters lost its only commercial vehicle in this accident and elected to cease operation by accepting the unsatisfactory safety rating.

Driver Information

The 67-year-old motorcoach driver possessed an Illinois class B commercial driver's license (CDL) with a P endorsement for passenger-carrying vehicles and an F restriction, which required the use of a left outside mirror.[7] The CDL was issued on August 8, 2001, and expired on September 14, 2005. According to the driver's wife, he had over 30 years of experience driving school buses, motorcoaches, a flat-bed truck, and a dump truck. The accident driver had no recorded accidents or traffic violations. Toxicological tests were negative for the presence of illicit drugs and alcohol.

The driver had a valid medical certificate. Medical records and reports from his wife indicate that he had undergone surgery for glaucoma in June 2004; had seen the ophthalmologist regularly; and, as indicated by records, was progressing well, without complications. He had a history of asthma, which was triggered by cigarette smoke and diesel fumes; he took two prescription medications and carried an inhaler to avoid acute flare-ups. His wife said he had not had an acute attack in nearly 6 years. The driver was also taking medication for high cholesterol, and his wife said he had not experienced any side effects.

[7] This restriction is normally issued to persons who have limited mobility to turn, hearing deficiencies, or sight-related impediments such as restricted peripheral vision. The motorcoach was equipped with external mirrors as required by the license restriction, which would have helped to mitigate existing limitations in the driver's horizontal visual field.

The accident driver's log for this trip was limited to entries for October 8, 2004. There were no logbook entries for October 9, but his activities were reconstructed based on distance traveled and witness interviews. Figure 7 outlines the truck driver's activities for October 7–9, 2004.

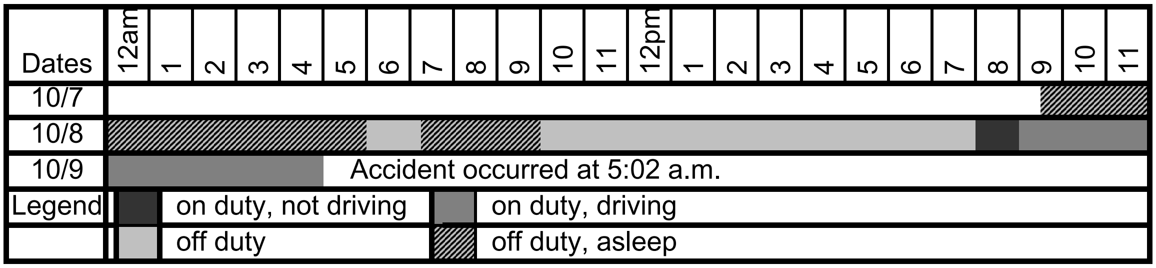

Figure 7. Duty status for motorcoach driver, October 7–9, 2004.

The driver's wife provided additional information on her husband's activities. He typically drove her to work about 6:15 a.m. and went to bed about 10:00–10:30 p.m. On October 7, he went to bed about 9:30 p.m.; the following morning he drove his wife to work as usual. She thought he returned home and slept until 10:00 a.m. At 2:00 p.m., she came home and they left to run errands, returning home about 4:30 p.m. After dinner, the driver rested in his recliner with his eyes closed until 6:00 p.m. They left the house about 6:50 p.m. to pick up the bus at the garage.

Surviving passengers said they were still boarding the bus at 8:45 p.m. and departed Chicago at 9:00 p.m. The driver had made two stops for restroom breaks; typically, he stopped at Effingham, Illinois, and then every 3 or 4 hours thereafter. None of the passengers could recall the time or location of the second stop. The driver's wife said she spoke to him about 10:00 p.m.

The driver had been awake for nearly 19 hours at the time of the accident. He had been on duty for 9 hours, of which the last 8 hours were spent driving. He had made two brief stops, the first one about 3 hours into the trip. The accident occurred on October 9 about 5:02 a.m., a time at which he usually was not driving but asleep—and a time of maximal sleepiness. Although the driver had obtained a full night's sleep on October 7 and had taken a nap during the day, the scheduling of the trip deprived him of his customary nighttime sleep period. He normally went to bed between 10:00–10:30 p.m., but on October 8 he left Chicago at 9:00 p.m. for an estimated 10-hour trip.

Research has revealed an association between time on task and increased risk of crash involvement.[8] A North Carolina study showed that drivers in sleep-related crashes had been driving for longer periods of time compared to those who were in nonsleep-related crashes. Driving between midnight and 6:00 a.m. and driving after being awake for more than 15 hours significantly increased a driver's risk of being involved in a sleep-related motor vehicle accident.[9] The accident driver took two restroom breaks, but it is unlikely that they provided much benefit from fatigue. Research has shown that such breaks provide only a short-term benefit for drivers who are already tired.[10]

The accident occurred about 5:02 a.m. Studies have shown that crashes caused by drivers falling asleep at the wheel are far more likely to occur at night. For example, an analysis of interstate truck crashes found that about twice as many occurred between midnight–8:00 a.m. as compared to other times, and about half of all single-vehicle crashes occurred in the early morning hours.[11] Research has shown that maximal sleepiness occurs between 3:00–5:00 a.m., with a lower peak in sleepiness between 3:00–5:00 p.m. Drivers working through the night are awake at a time when their body is programmed to sleep.[12]

Based on reconstructed vehicle dynamics, the motorcoach made a directional change to the right, most likely after contacting the milled rumble strips adjacent to the left pavement edge lane. Rumble strips are designed to provide tactile or auditory alerts for the driver. In most situations, rumble strips are effective in reducing the number and severity of run-off-the-road accidents.[13] However, in this case, the vibration and noise made by the tires on the rumble strips may have startled the driver, causing him to steer abruptly and excessively (as evidenced by the vehicle's path) and sending the motorcoach off the right side of the road, which likely initiated the rotation of the vehicle.

[8] (a) W. Harris, R. Mackie, and others, *A Study of Relationships Among Fatigue, Hours of Service, and Safety Operations of Truck and Bus Drivers*, BMCS-RD-71-2 (Washington, DC: U.S. Department of Transportation, 1972). (b) I.S. Jones and H.S. Stein, *Effect of Driver Hours of Service on Tractor-Trailer Crash Involvement* (Washington, DC: Insurance Institute for Highway Safety, 1987).

[9] J.C. Stutts, J.W. Wilkins, J.S. Osberg, and B.V. Vaughn, "Driver Risk Factors for Sleep-Related Crashes," *Accident Analysis and Prevention* Vol. 35 (2003): 321–331.

[10] N. Haworth, "The Role of Fatigue in Setting Driving Hour Regulations," *Fatigue and Driving: Driver Impairment, Driver Fatigue, and Driving Simulation*, ed., L. Hartley (Bristol, PA: Taylor & Francis, 1995).

[11] W. Harris, "Fatigue, Circadian Rhythm, and Traffic Accidents," *Vigilance Theory, Operational Performance, and Physiological Correlates*, ed., R.R. Mackie (New York: Plenum, 1977) 133–146.

[12] T. Roth, T.A. Roehrs, M.A. Carskadon, and W.C. Dement, "Daytime Sleepiness and Alertness," *Principles and Practice of Sleep Medicine*, eds., M.H. Kryger, T. Roth, and W.C. Dement (Philadelphia, PA: Sanders, 1994).

[13] (a) J.J. Hickey, "Shoulder Rumble Strip Effectiveness: Drift-Off-Road Accident Reductions on the Pennsylvania Turnpike," *Transportation Research Record*, 1573 (Washington, DC: National Research Council/ Transportation Research Board, 1997). (b) D.A. Morena, "Rumbling Towards Safety," *Public Roads* Vol. 67, No. 2 (2003). (c) R.R. Marvin and D.J. Clark, *An Evaluation of Shoulder Rumble Strips in Montana*, FHWA/ MT-03-008/8157 (Washington, DC: Federal Highway Administration, 2003).

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the motorcoach driver's fatigued condition, which led him to drift from the left side of the roadway, contact rumble strips, oversteer to the right, and then move off the roadway. The detachment of the motorcoach roof was a contributing cause to the severity of injuries and the number of ejections.

Adopted: August 22, 2008