Truck-Tractor Semitrailer Rear-End Collision Into Passenger Vehicles on Interstate 44 Near Miami, Oklahoma June 26, 2009

Accident Report

NTSB/HAR-10/02
PB2010-916202

National Transportation Safety Board

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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. 2010. ***Truck-Tractor Semitrailer Rear-End Collision Into Passenger Vehicles on Interstate 44, Near Miami, Oklahoma, June 26, 2009.*** **Highway Accident Report NTSB/HAR-10/02. Washington, DC.**

Abstract: About 1:19 p.m. on June 26, 2009, a multivehicle accident occurred on Interstate 44 (I-44) near Miami, Oklahoma, shortly after a minor accident in the vicinity had resulted in a traffic queue. A truck driver operating a Volvo truck-tractor in combination with an empty semitrailer was traveling eastbound in the outside lane of I-44. He did not react to the queue of slowing and stopped vehicles ahead and collided with the rear of a Land Rover sport utility vehicle (SUV). As both vehicles moved forward, the Land Rover struck a Hyundai Sonata and then departed the right lane and shoulder. The Volvo continued forward, struck and overrode the Hyundai Sonata, struck and overrode a Kia Spectra, and then struck the rear of a Ford Windstar minivan. The Volvo overrode a portion of the Windstar while pushing it into the rear of a trailer being towed by a Ford F350 pickup truck. The pickup was pushed into a Chevrolet Tahoe SUV. As a result of the accident, 10 passenger vehicle occupants died, 5 received minor-to-serious injuries, and the Volvo combination unit driver was seriously injured.

The major safety issues identified were the accident truck driver's fatigue, the need for updated and comprehensive fatigue education materials and fatigue management programs, the significance of heavy vehicle aggressivity in collisions between dissimilar vehicles, the lack of Federal requirements for heavy commercial vehicle event data recorders and video event recorders, and the lack of Federal requirements for forward collision warning systems.

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Acronyms and Abbreviations

21CTP	21st Century Truck Partnership
AASHTO	American Association of State Highway and Transportation Officials
ABS	antilock braking system
ACC	adaptive cruise control
AMTA	Alberta Motor Transport Association
ATA	American Trucking Associations, Inc.
AWG	Associated Wholesale Grocers, Inc.
BMI	body mass index
CDL	commercial driver’s license
CFR	*Code of Federal Regulations*
CMB	collision mitigation braking
CMV	commercial motor vehicle
CPAP	continuous positive airway pressure
CVSA	Commercial Vehicle Safety Alliance
CWS	collision warning system
CY	calendar year
DfT	U.K. Department for Transport
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DVIR	Driver’s Vehicle Inspection Report
ECE	Economic Commission for Europe (United Nations)
ECM	electronic control module
EDR	event data recorder
ESC	electronic stability control
FAA	Federal Aviation Administration
FARS	Fatality Analysis Reporting System
FCWS	forward collision warning system
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration

FMCSRs	*Federal Motor Carrier Safety Regulations*
FMVSSs	*Federal Motor Vehicle Safety Standards*
FOT	field operational test
FUPS	front underride protection system
g	acceleration of gravity
GPS	global positioning system
GVWR	gross vehicle weight rating
HOS	hours of service
I-44	Interstate 44
ITS	intelligent transportation system
IVBSS	integrated vehicle-based safety system
IVI	Intelligent Vehicle Initiative
Mobius OBC	Mobius TTS on-board computer
MUTCD	*Manual on Uniform Traffic Control Devices*
NAFMP	North American Fatigue Management Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
OFM	Operator Fatigue Management
OHP	Oklahoma Highway Patrol
OOS	out of service
OSA	obstructive sleep apnea
OTA	Oklahoma Turnpike Authority
RITA	Research and Innovative Technology Administration
SAE	SAE International
SafeStat	Motor Carrier Safety Status Measurement System
SDD	sudden deceleration data
SUV	sport utility vehicle
UMTRI	University of Michigan Transportation Research Institute
VC-COMPAT	*Improvement of Vehicle Crash Compatibility Through the Development of Crash Test Procedures*
VER	video event recorder

Executive Summary

On June 26, 2009, a multivehicle accident occurred on Interstate 44 (I-44) near Miami, Oklahoma, shortly after a minor accident in the same vicinity occurred. The minor accident took place about 1:13 p.m., when a 2001 Ford Focus traveling eastbound at milepost 321.7 on I-44 drifted into a truck-tractor semitrailer parked on the right shoulder. After the Focus sideswiped the semitrailer, the car's driver overcorrected to the left, lost control, and struck the concrete center median barrier. The Focus came to rest in the roadway, blocking the left eastbound lane. As the trailing traffic began to slow and stop, it formed a queue. Several motorists exited their vehicles and began to push the disabled Focus to the right shoulder. The queue of stopped vehicles and approaching but slowing vehicles extended back from the accident site approximately 1,500 feet to about milepost 321.5.

Meanwhile, about 1:19 p.m., a 76-year-old truck driver operating a 2008 Volvo truck-tractor in combination with an empty 2009 Great Dane refrigerated semitrailer was traveling eastbound in the outside (right) lane of I-44 at approximately 69 mph. (The posted speed limit was 75 mph.) The truck driver did not react to the queue of slowing and stopped vehicles and collided with the rear of a 2003 Land Rover sport utility vehicle (SUV). As both vehicles moved forward, the Land Rover struck a 2003 Hyundai Sonata and then departed the right lane and shoulder, coming to rest off the roadway. The Volvo continued forward, struck and overrode the Hyundai Sonata, struck and overrode a 2004 Kia Spectra, and then struck the rear of a 2000 Ford Windstar minivan. The Volvo overrode a portion of the Windstar while pushing it into the rear of a livestock trailer being towed by a 2004 Ford F350 pickup truck. The pickup truck was pushed forward and struck a 2008 Chevrolet Tahoe SUV. The Volvo combination unit came to rest approximately 270 feet past the point where it initially struck the Land Rover. As a result of the Volvo combination unit's striking the slowed and stopped vehicle queue on I-44, 10 passenger vehicle occupants died, 5 received minor-to-serious injuries, and the driver of the Volvo combination unit was seriously injured.

The National Transportation Safety Board determines that the probable cause of this accident was the Volvo truck driver's fatigue, caused by the combined effects of acute sleep loss, circadian disruption associated with his shift work schedule, and mild sleep apnea, which resulted in the driver's failure to react to slowing and stopped traffic ahead by applying the brakes or performing any evasive maneuver to avoid colliding with the traffic queue. Contributing to the severity of the accident were the Volvo truck-tractor combination unit's high impact speed and its structural incompatibility with the passenger vehicles.

The following safety issues are identified in this report:

- The accident truck driver's fatigue,
- The need for updated and comprehensive fatigue education materials and fatigue management programs,
- The significance of heavy vehicle aggressivity in collisions between dissimilar vehicles,

- The lack of Federal requirements for heavy commercial vehicle event data recorders and video event recorders, and
- The lack of Federal requirements for forward collision warning systems.

As a result of its investigation, the National Transportation Safety Board (NTSB) is making four recommendations to the Federal Motor Carrier Safety Administration (FMCSA), four to the National Highway Traffic Safety Administration (NHTSA), and one to Associated Wholesale Grocers, Inc. The NTSB also reiterates and reclassifies one recommendation to the U.S. Department of Energy and two recommendations to NHTSA, reiterates two recommendations to the FMCSA and one recommendation to NHTSA, and reclassifies one recommendation to NHTSA.

Factual Information

Accidents

About 1:13 p.m.[1] on June 26, 2009, a minor traffic accident involving a Ford Focus occurred on eastbound Interstate 44 (I-44), the Will Rogers Turnpike, near Miami, Oklahoma. Immediately following this minor accident, a queue of traffic formed as the disabled vehicle was pushed from the roadway. Within minutes of the first accident, at approximately 1:19 p.m., a secondary fatal accident occurred when a Volvo truck-tractor semitrailer drove into the traffic queue at approximately 69 mph. (See figures 1 and 2 for postaccident photographs. Figure 3 shows a map of the accident location.)

Figure 1. View of I-44 (looking west) showing the site of the fatal June 26, 2009, accident. [Photograph courtesy Gary Crow]

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

Figure 2. Postaccident photograph showing Volvo truck-tractor semitrailer override of passenger vehicles. [Photograph courtesy Oklahoma Highway Patrol]

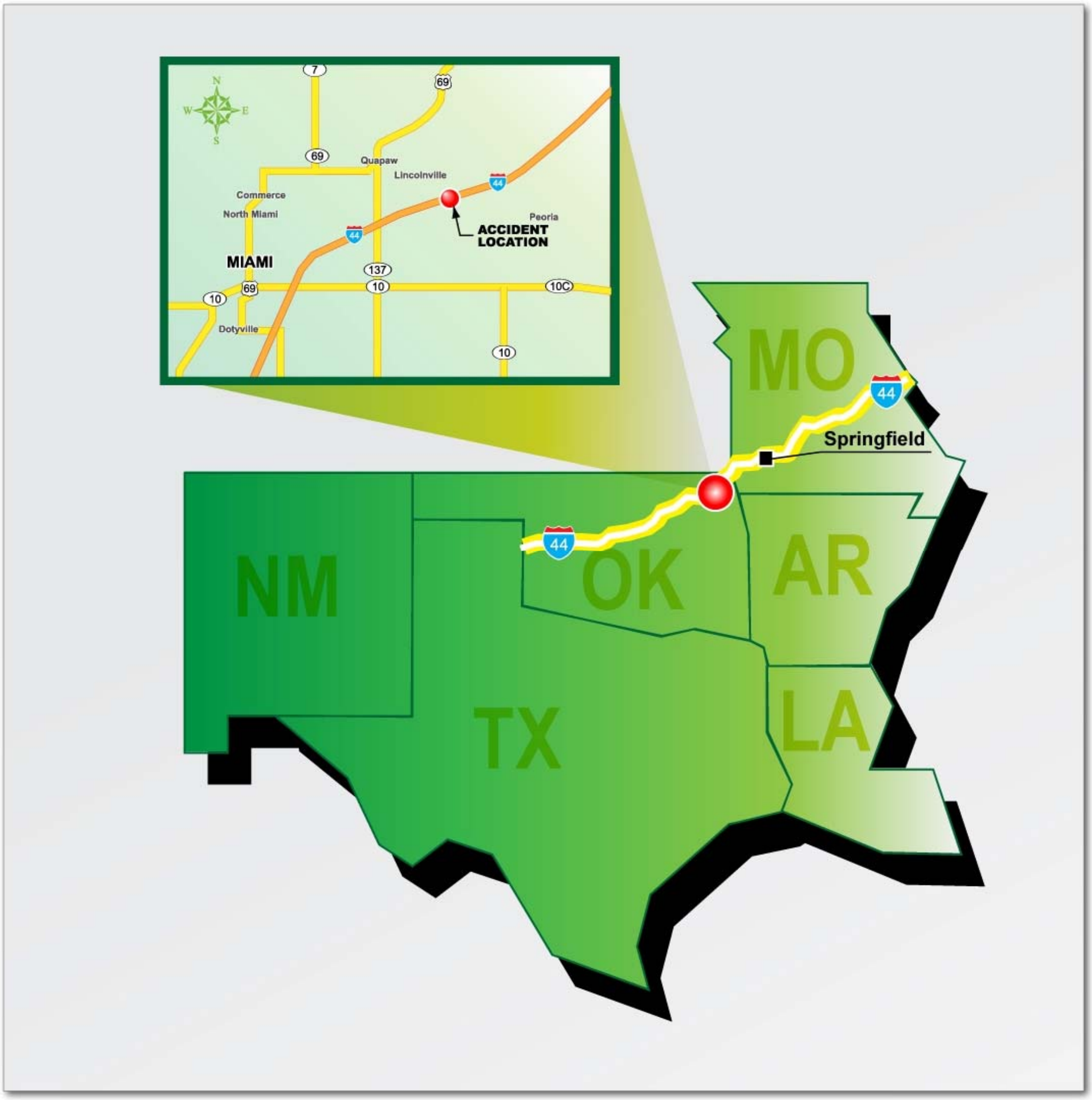

Figure 3. Accident location map.

At the times of both accidents, the pavement was dry, and the nearest weather station reported conditions of clear, dry weather with 10 miles of visibility and a temperature of approximately 101° F and 43 percent humidity. When the accidents occurred, the sun was almost directly overhead.

Initial Accident (Minor)

The first accident involved a 2001 Ford Focus that drifted from the right travel lane on eastbound I-44 and sideswiped a 2007 Kenworth truck-tractor with a refrigerated semitrailer that was parked on the right-hand shoulder. The driver of the truck-tractor semitrailer had pulled onto the shoulder to check his semitrailer. The Oklahoma Highway Patrol (OHP) interviewed the 18-year-old driver of the Focus, who stated that the traffic was sparse when the accident occurred. She said she believed that she fell asleep, drifted to the right, and then woke up when her vehicle sideswiped the left rear tires of a parked truck-tractor semitrailer on the right shoulder. The Focus had traveled about 1 foot out of the right lane and onto the highway shoulder when it sideswiped the tires. As the Focus driver corrected toward the left, her vehicle began to rotate (counterclockwise), entered the left lane and then the left shoulder, and finally hit the concrete median barrier head-on. The Focus came to rest blocking the left lane, facing oncoming traffic in the left lane of I-44[2] near milepost 321.7.

The driver and passenger of the parked truck-tractor semitrailer and a passerby from another vehicle assisted the Focus driver, and they began to push the car out of the travel lanes. Approaching vehicles started to slow and stop for the Focus accident, and a queue of slowing and stopped vehicles extended behind the accident site for approximately 1,500 feet, from about milepost 321.7 back to about milepost 321.5.

Second Accident (With Fatalities)

As vehicles approached the traffic queue, they decelerated from the posted speed limit of 75 mph. The 2008 Volvo truck-tractor with an empty 2009 Great Dane refrigerated semitrailer, traveling eastbound at approximately 69 mph, struck the last vehicle in the right lane of the queue without significant slowing. The entire combination vehicle weighed approximately 40,400 pounds. At initial impact, the Volvo combination unit struck a 2003 Land Rover sport utility vehicle (SUV), pushing it forward into a 2003 Hyundai Sonata passenger car; the Land Rover continued to the right, where it overturned and came to rest on the grass off the roadway shoulder. The Volvo combination unit continued forward an additional approximately 42 feet and collided with the Hyundai, overriding it. Both vehicles moved forward about 29 feet, at which point, the Volvo combination unit struck and overrode a 2004 Kia Spectra passenger car.

The Volvo combination unit (with the two passenger vehicles by then caught underneath it) continued forward until it struck and partially overrode a 2000 Ford Windstar minivan. The minivan was pushed forward into the rear of a 16-foot-long livestock trailer (loaded with 10 sheep) being towed by a 2004 Ford 350 pickup truck. The F350 pickup truck was then pushed forward into a 2008 Chevrolet Tahoe SUV. The Volvo combination unit came to rest on top of the Hyundai, the Kia, and a portion of the Ford Windstar minivan. From the initial impact to final rest, the Volvo combination unit traveled approximately 270 feet. (See figure 4.)

[2] The Focus had scrape and scuff marks along its passenger side from the parked truck-tractor semitrailer's tires, beginning at the rear passenger door and continuing along the right rear quarter panel. There were additional scrape marks and damage to the right rear wheel.

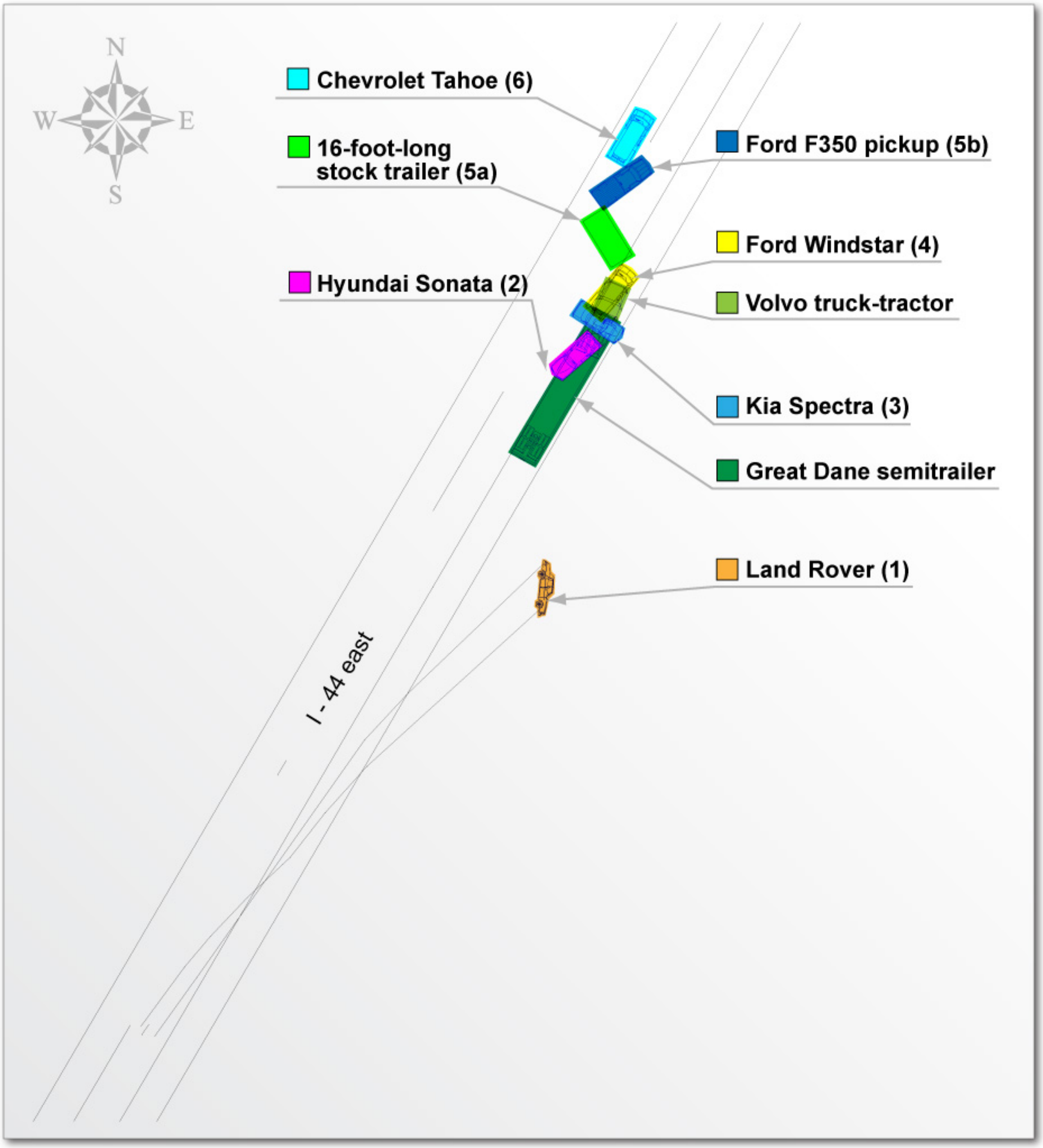

Figure 4. Postaccident scene diagram showing all involved vehicles in final at-rest positions. (Numbers in parentheses show the order in which the vehicles were struck.)

The pavement at the accident scene showed gouges from the undercarriages of the struck passenger vehicles. The pavement also showed tire friction marks from the overridden passenger vehicles and from the Volvo combination unit, which resulted when all of the unit's spring brakes locked after its air system was damaged. These marks began at the initial impact point and continued until the combination unit came to a final stop near a drainage structure adjacent to the roadway.

Damage to Vehicles Involved in Fatal Accident

Volvo Truck-Tractor Semitrailer

As a result of the second accident, the Volvo truck-tractor sustained extensive damage and its Great Dane semitrailer sustained minor damage. (See figure 5.) The Volvo truck-tractor sustained frontal damage, including windshield damage. The body of the truck-tractor was shifted to the right, and there was right side damage to the front of the frame. Additional damage was located underneath the vehicle. The brake components on the Volvo steer and second axles were damaged as a result of the accident. Near the second axle, damage consisting of gouging and scraping to the driveshaft and axle housing was found, and the second axle brake components were bent. The underside of the right side saddle fuel tank was damaged, and fuel was lost through a hole in the underside of the tank.

Figure 5. Collision damage to 2008 Volvo truck-tractor.

The Volvo truck-tractor's interior did not sustain damage, the steering wheel was not damaged, and the driver airbag did not deploy.[3]

[3] The nature of this collision and the absence of cab deformation indicate that the crash forces imparted upon the driver were not of sufficient magnitude to warrant deployment of the airbag.

Vehicles Struck in Fatal Accident

In total, the second accident involved six passenger vehicles and a livestock trailer. (See appendix B for photographs of the six passenger vehicles and the livestock trailer involved in the fatal accident.) Four of the passenger vehicles were destroyed by impact, and the F350 pickup truck (and its livestock trailer) and the Chevy Tahoe had moderate damage.

Land Rover SUV. Postaccident inspection revealed significant override damage where the Land Rover's left rear bumper corner was crushed 19 inches forward of the rear axle, and the passenger compartment interior was almost two-thirds collapsed toward the front of the vehicle. A small area on the right side of the rear seat had not collapsed. The vehicle also sustained damage to its left front bumper corner and down the left side of its front fender, due to impact with the back of the Hyundai sedan.

Hyundai Sonata Sedan. The Volvo truck-tractor completely overrode the Hyundai and, when all the vehicles came to rest, the Volvo was on top of the Hyundai. Black tire marks were found on the top of the Hyundai's rear center seat and on the driver's headrest. The entire back end of the Hyundai was crushed inward, the roof was crushed downward, the corner of the right rear bumper was crushed forward approximately 36 inches, and the interior of the vehicle was almost totally collapsed downward.

Kia Spectra Sedan. The Volvo truck-tractor struck, overrode, and came to rest completely on top of the Kia. Postaccident inspection revealed that the Kia's entire rear portion was crushed inward, the roof was crushed downward, and the left rear bumper corner was crushed forward approximately 18 inches. The seatbacks were partially collapsed downward.

Ford Windstar Minivan. The Volvo truck-tractor semitrailer's striking the Windstar resulted in the rear two-thirds of the minivan being trapped underneath the front of the Volvo when all the vehicles came to final rest. The Windstar was crushed forward and upward off the frame, and its roof was bent accordion-style forward and upward at a 90-degree angle and torn away from the D-pillar. The left rear bumper corner was crushed forward to the rear axle, and the vehicle's entire front end sustained moderate damage from striking the livestock trailer being towed by the F350 pickup truck. The interior of the minivan was almost totally collapsed forward, with the exception of the right front passenger seatback.

Ford F350 Pickup Truck and Livestock Trailer. The F350 pickup truck was towing a livestock trailer, which was struck by the Ford Windstar minivan. The right rear sidewall of the livestock trailer sustained approximately 30 inches of crush, pushing the loading gates inward, buckling the roof up and forward, and bowing the trailer's left sidewall outward approximately 20 inches. The front of the livestock trailer was deformed from being pushed into the pickup's rear bumper and then pushed forward into its bed. The pickup's bed bowed outward to the right and forward into the back of the passenger cab, cracking the rear window glazing. As the F350 pickup truck was pushed forward, it struck a Chevrolet Tahoe SUV in the right lane, and its left front bumper corner sustained 17 inches of direct contact damage and was crushed rearward approximately 15 inches. The pickup truck sustained no interior damage.

Chevrolet Tahoe SUV. This vehicle was struck from behind by the Ford pickup truck, and it came to rest in the left lane. The vehicle exterior sustained moderate damage, consisting of approximately 12 inches of direct contact damage, which continued down the right rear fender and caused the right rear window to shatter. The interior of the vehicle sustained no damage.

Survival Factors

As a result of the Volvo combination unit's collision into the passenger vehicles, 10 passenger vehicle occupants died, and 5 received injuries ranging from minor to serious. The driver of the Volvo truck-tractor combination unit sustained serious injuries. (See tables 1 and 2.)

Table 1. Injuries.

Injury Severity[a]	Volvo Truck Driver	Passenger Car Occupants	Total
Fatal	0	10	10
Serious	1	3	4
Minor	0	2	2
None	0	5	5
Total	1	20	21

[a]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, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface."

Table 2. Passenger vehicle occupant information.

Vehicle	Occupant	Seating Position	Restraint	Injury
2008 Volvo Truck	76-year-old male	Driver	Lap/shoulder (not used)	Serious
2003 Land Rover	49-year-old male	Driver	Lap/shoulder (not used)	Fatal
	51-year-old female	Front right	Lap/shoulder (not used)	Fatal
	12-year-old female	Rear right	Lap/shoulder	Serious
2003 Hyundai Sonata	38-year-old male	Driver	Lap/shoulder	Fatal
	34-year-old female	Front right	Lap/shoulder	Fatal
	06-year-old male	Rear left	Lap/shoulder with booster seat	Fatal
	55-year-old female	Rear right	Lap/shoulder	Fatal
2004 Kia Spectra	52-year-old female	Driver	Lap/shoulder (not used)	Serious
	05-year-old female	Rear left	Lap/shoulder with booster seat	Minor
	06-year-old male	Rear right	Lap/shoulder with booster seat	Minor
2000 Ford Windstar	79-year-old male	Driver	Lap/shoulder	Fatal
	73-year-old female	Front right	Lap/shoulder	Fatal
	71-year-old female	Rear left	Lap/shoulder	Fatal
	52-year-old male	Rear right	Lap/shoulder	Fatal
2004 Ford F350	41-year-old male	Driver	Lap/shoulder	None
	12-year-old female	Front right	Lap/shoulder	None
2008 Chevrolet Tahoe	69-year-old male	Driver	Lap/shoulder	None
	62-year-old female	Front right	Lap/shoulder	Serious
	12-year-old female	Rear left	Lap/shoulder	None
	12-year-old female	Rear right	Lap/shoulder	None

Postaccident examinations of those killed in the accident showed that their injuries included blunt force trauma to the head and torso, fractures of the extremities, and multiple severe abrasions and lacerations. Three occupants of the passenger vehicles sustained chemical contact injuries from the fuel that leaked from the damaged saddle fuel tank of the Volvo truck-tractor when it came to rest on top of their vehicles. The surviving passenger in the Land Rover and the driver of the Kia were seriously injured, suffering blunt force trauma injuries to the chest and internal organs, as well as multiple fractures (ribs, pelvis, and extremities). The front right passenger of the Chevy Tahoe sustained a serious head injury. The Kia's two rear-seat child passengers sustained minor injuries consisting of contusions, lacerations, and abrasions.

The driver of the Volvo truck-tractor semitrailer was not wearing his 3-point restraint, and he sustained injuries including a nondisplaced fracture of the jaw, a brain contusion, and facial swelling and lacerations.

Emergency Response

The Miami Police Department dispatcher was notified of the fatal accident through the 911 system at 1:20 p.m. An OHP trooper, who was working a vehicle incident a short distance west of the accident, was notified of the accident by a passerby and was en route to the scene when dispatch notified him at 1:22 p.m. Upon his arrival on scene at 1:24 p.m., the trooper assumed Incident Command for law enforcement and immediately requested OHP dispatch to send all available ambulances, three medical helicopters, and a heavy-duty wrecker, stating that there were injuries and people pinned in their vehicles. The trooper also requested that the Oklahoma Turnpike Authority (OTA) close the eastbound tollgate in Miami and start rerouting traffic. By 1:33 p.m., eastbound traffic on the I-44 turnpike was closed, and traffic was redirected off at the Miami tollbooth. Westbound traffic was reduced to one lane.

The first call from dispatch went out to the Downstream Fire Department at 1:22 p.m., and its first unit arrived on scene at 1:31 p.m. The Miami Fire Department was notified of the accident at 1:23 p.m., and its first unit arrived on scene at 1:33 p.m. The arriving shift captain for the Downstream Fire Department assumed Incident Command for the rescue, recovery, extrication, and transport of the injured. Between 1:33 and 1:38 p.m., three medical helicopters were put on standby; they were subsequently dispatched to the scene, sequentially. Each helicopter transported one seriously injured passenger vehicle occupant to hospitals in Joplin, Missouri. The Volvo driver and the seriously injured Tahoe passenger were transported to a hospital by ground ambulance at 2:29 p.m.

A heavy-duty wrecker arrived approximately 40 minutes after the first call from dispatch.[4] According to the wrecker owner/driver, he took the most direct route to the accident scene, a distance of about 15 miles. Because of the backed-up traffic, he had to drive his wrecker along the shoulder and, at times, into the drainage ditch to get to the scene. The Volvo combination unit had come to rest on top of three passenger vehicles; consequently, the Volvo truck-tractor and its semitrailer had to be lifted off the Kia and the Hyundai before the occupants could be extricated. In total, 7 fire departments, with 7 rescue and engine units, and 12 public and private emergency medical services ambulances responded to the scene, as well as 3 medical helicopters.

Highway Information

General

The fatal accident occurred on I-44 eastbound about milepost 321.5. The accident site was about 8 miles northeast of the city of Miami in Ottawa County, Oklahoma. I-44, also called the Will Rogers Turnpike, is a four-lane limited access highway with dual east- and westbound

[4] Dispatch notified the closest heavy-duty wrecker service, which was also considered the most experienced to handle this service call.

lanes separated by a 29-inch-high concrete median barrier.[5] The two lanes in each direction were 11.50 feet wide and were delineated by long, dashed white-painted stripes. A solid white-painted stripe separated each direction's right-hand lane from the 10-foot-wide right shoulder, and both directions had alerter grooves (rumble strips) cut into the pavement shoulder.[6] The left median shoulder was 7.50 feet wide and delineated from the main travel lane by a solid yellow pavement stripe.

The roadway was directionally straight from eastbound milepost 320.00 to 323.50; the fatal accident occurred about milepost 321.50. About 5,865 feet west of the accident, a 1,800-foot-long crest vertical curve[7] began. The roadway had a 3.00-percent downgrade for approximately 1,200 feet that transitioned into a 900-foot-long sag curve[8] with a 1.70-percent downgrade that transitioned into a 1.13-percent upgrade. I-44 was classified as a principal rural arterial with a posted speed limit of 75 mph.[9]

The OTA conducted a speed survey on I-44 in the week after the accident, and the 85th percentile speeds for commercial trucks and passenger cars were 78 and 77 mph, respectively.

The American Association of State Highway and Transportation Officials (AASHTO) recommends an 820-foot stopping sight distance for a speed of 75 mph.[10] Field measurements showed that when the accident site was viewed from a truck driver's perspective (average seated eye height of approximately 96 inches from the ground), a 2.0-foot-tall (height of a passenger car taillight) object could be seen from the beginning of the hill crest 1,260 feet away.[11] (See figure 6.)

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[5] Such barriers are commonly referred to as Jersey barriers, and they are tested to meet test level 4 crash parameters (as detailed in National Cooperative Highway Research Program [NCHRP] Report 350).

[6] The slope adjacent to the roadside was a 4H:1 traversable slope.

[7] A "crest vertical curve" may be called a "hill crest."

[8] Vertical curves are used to effect gradual changes between tangent grades at their point of intersection. Vertical curves that are offset above the tangent are defined as "sag vertical curves."

[9] The design speed for this segment of highway was also 75 mph.

[10] "Stopping sight distance" is defined as a sum of two distances: (1) the distance traversed by the vehicle from the instant the driver sees an object necessitating a stop to the instant that the brakes are applied, and (2) the distance needed to stop the vehicle from the instant brake application begins. AASHTO guidelines state that recommended stopping sight distances are based on passenger car operation and do not explicitly consider truck operation because a truck driver is able to see substantially farther beyond vertical sight obstructions than a passenger car driver due to the higher position of the driver's seat in the truck. The greater sight distance is considered to balance the greater distance the larger and heavier truck needs to come to a stop from the same given speed as the smaller and lighter passenger car. (Per *A Policy on Geometric Design of Highways and Streets*, 5th edition [Washington, DC: American Association of State Highway and Transportation Officials, 2004], p. 110.)

[11] For a passenger car driver's seated height, the stopping sight distance was 975 feet.

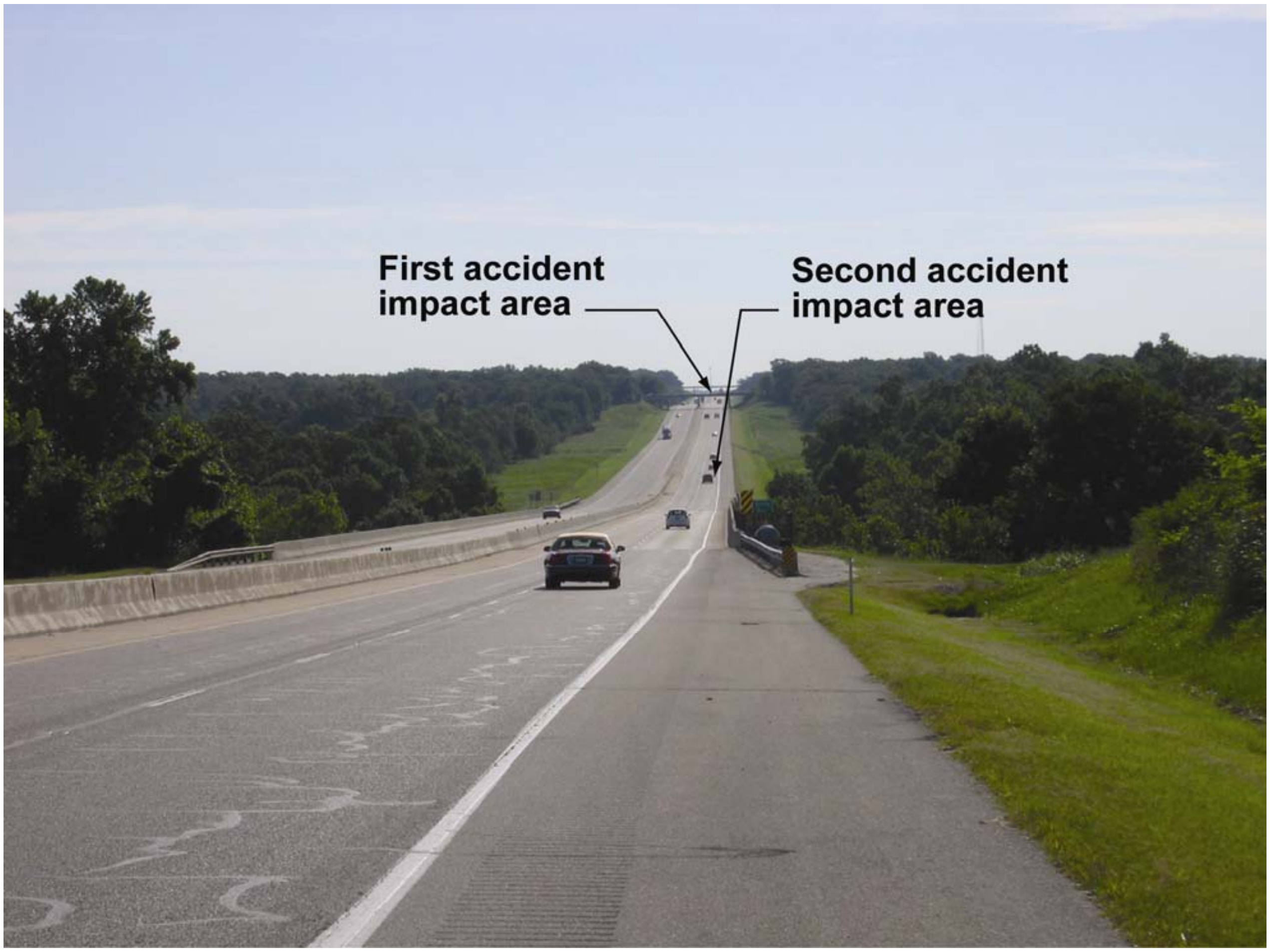

Figure 6. View of I-44 eastbound, showing the sites of the June 26, 2009, accidents.

Accident records from the OTA showed that for a 5-year period prior to the accident (2004–2008), there were 70 accidents along the 6-mile segment between mileposts 318.5 and 324.5. Comprising the 70 events were 31 injury accidents, 2 fatal accidents (1 of which involved a commercial vehicle), and 37 property damage accidents. The annual average daily traffic count for 2004–2008 was 20,642 vehicles per day for I-44. The OTA indicated that commercial vehicles accounted for approximately 35 percent of this total.

Traffic Incident Control

The state of Oklahoma has adopted the Federal *Manual on Uniform Traffic Control Devices* (MUTCD). Chapter 6I of this manual provides guidance for the safe movement of vehicles through incident management areas, such as accidents, by establishing procedures for temporary traffic control. The MUTCD provides guidance to state emergency response and transportation agencies on what to do within the first 15 minutes of arriving on scene. The MUTCD guidance advises them to determine the magnitude of the traffic incident and to estimate the expected duration of the incident and the expected vehicle queue lengths; then, responders should set up the appropriate temporary traffic controls based on these estimates.[12] The initial accident that caused the traffic queue to develop occurred at approximately 1:13 p.m.; the fatal accident occurred at 1:19 p.m., and the first responding OHP trooper arrived on scene at 1:24 p.m.

Volvo Truck-Tractor Semitrailer

General

The vehicle that rear-ended the passenger cars in the fatal accident was a 2008 Volvo truck-tractor with an empty 2009 Great Dane refrigerated semitrailer. The unloaded Volvo combination unit weighed 40,400 pounds. Both the truck-tractor and the semitrailer were owned by Associated Wholesale Grocers, Inc. (AWG).

The truck-tractor and the semitrailer were equipped with an antilock braking system (ABS) and electronic stability control (ESC). The ABS monitors wheel speed and modulates the brakes of the vehicle, preventing wheel lock-up and increasing controllability in the event of emergency braking. The *Federal Motor Vehicle Safety Standards* (FMVSSs) require all pneumatically braked trucks and trailers manufactured after March 1998 to have ABS. ESC is a system that builds onto the ABS of a vehicle by monitoring the steering angle against directional acceleration and rotation to help guide the vehicle in the intended direction of travel.[13]

AWG had an in-house maintenance facility for its vehicles at its terminal in Springfield, Missouri. AWG serviced its truck-tractors according to a service inspection program under which they were inspected and serviced by mechanics every 13,500 miles, and the semitrailers were inspected and serviced every 4 months.

AWG vehicles were subject to the annual inspection requirement under the *Federal Motor Carrier Safety Regulations* (FMCSRs), in accordance with 49 CFR 396.17. The company's mechanics reportedly inspected each vehicle in accordance with the regulation, and AWG vehicles passing the inspection received an affixed label indicating passage. The Volvo truck-tractor passed the annual U.S. Department of Transportation (DOT) inspection in March 2009. The Great Dane semitrailer was serviced, and it received an annual DOT inspection sticker, in April 2009. The truck-tractor had last received preventive maintenance service on June 16, 2009.

According to company policy, AWG mechanics were to check the tires on the truck-tractors every morning for wear and proper tire pressure. Drivers were responsible for

[12] *Manual on Uniform Traffic Control Devices*, Chapter 6I, "Control of Traffic Through Traffic Incident Management Areas" (Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 2003).

[13] ESC is not currently required for vehicles with gross vehicle weight ratings (GVWRs) over 10,000 pounds. The FMVSSs require all passenger vehicles, trucks, and buses with GVWRs of 10,000 pounds or less manufactured after September 2011 to be equipped with ESC. (Per 49 CFR Part 571, Standard 126.)

conducting pre- and post-trip inspections of their truck-tractors every trip (per 49 CFR 396.11 and 396.13). The drivers were to complete a Driver's Vehicle Inspection Report (DVIR) that recorded their findings; the DVIRs were to be kept in a book in the tractor. According to AWG, the mechanics reviewed the DVIR defect reports daily, made repairs in a timely manner, and then signed the DVIRs and notified the drivers. The National Transportation Safety Board (NTSB) obtained copies of the AWG's DVIRs and associated repair records for the accident vehicle. A review of the reports indicated that the standard AWG procedures were followed.

Following the accident, the truck-tractor's cruise control was found in the "on" position. Photographs taken at the accident scene show the driver's window rolled down. The Volvo's three ventilation controls to the right of the steering wheel indicated that the temperature was set to "cold," the fan strength was set to "medium," and the fan was set to blow at both the upper and lower vents. It could not be determined whether the air conditioning was on or off at the time of the accident.

Electronic Control Module

The accident tractor's Cummins ISX diesel engine was electronically controlled and equipped with an electronic control module (ECM). The ECM is responsible for controlling engine timing, fuel delivery, speed control, and other parameters and is capable of capturing and preserving limited operating data related to sudden deceleration. "Sudden deceleration events" are triggered or recognized when the calculated deceleration rate of the vehicle meets or exceeds a predetermined threshold or value. Although the ECM was designed with this sudden deceleration event recording capability, it also stored additional data that could be relevant to understanding a crash, such as diagnostic conditions, engine data, ECM calibrations, and trip information.[14]

The ECM contained three sudden deceleration data (SDD) events.[15] These SDD event records were designed to capture 60 seconds of pre-event data and 15 seconds of data following the event trigger. Although the ECM was designed with an event data recorder (EDR) function, it was not designed or intended to capture the amount and type of high-resolution data that would have been available had the truck-tractor been equipped with an advanced or dedicated crash EDR intended to assist in the reconstruction of complex accident events.[16] Postaccident examination of the ECM data revealed that the ECM's road speed governor configuration was enabled and configured to limit the vehicle's maximum road speed to 70 mph and that the truck-tractor semitrailer was traveling at 70 mph when it struck the first slowed or stopped vehicle. However, NTSB analysis of vehicle speed input data yielded results that indicated that the effect of the Volvo's worn drive axle tires resulted in a minor "over-reporting" of vehicle

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[14] The accident Volvo was equipped with a driver supplemental restraint system or airbag. Recent iterations of the Volvo heavy vehicle airbag control module are capable of limited data collection in connection with detected "crash" (airbag deploys) and "near crash" (airbag does not deploy) events.

[15] The ECM stored the three most recent SDD events. The most recent SDD event correlated with this accident.

[16] An EDR is defined by the National Highway Traffic Safety Administration (NHTSA) within 49 CFR Part 563 as a device or function that records a vehicle's dynamic, time-series data just before a crash (vehicle speed versus time) or during a crash (change in velocity versus time).

speed by 1.36 to 1.40 mph when the Volvo was operating in 10th gear and within the 69- to 71-mph speed range. On this basis, the ECM-reported vehicle speed of 70 mph at the time of the accident was approximately 1.38 mph too high, indicating an actual road speed at time of impact of approximately 68.70 mph.

The available ECM data also indicated that the tractor's cruise control was active and that the driver did not attempt to brake the Volvo before striking the passenger vehicles or at any time during the accident sequence.

Cadec Mobius TTS On-Board Computer System

AWG equipped its vehicles, including the accident tractor, with the Cadec Global, Inc., Mobius TTS on-board computer (Mobius OBC) system, a computerized on-board driver interface used to electronically record DOT hours of service (HOS) logs. The system includes a global positioning system (GPS). The Mobius OBC is designed to serve as a fleet management system, providing the carrier with data analysis and reporting capabilities to optimize mobile resources, improve driver performance, and meet DOT HOS compliance and safety requirements. Consisting of a recording device hard-wired into the engine, the Mobius OBC records the driver's driving activities electronically.[17]

All Mobius OBCs are equipped with a 12-channel GPS receiver used to produce detailed records of the vehicle's operation. The Mobius OBC also has several additional features, including the ability to capture limited data in connection with a driver-reported accident event, sudden deceleration, or unknown stop. Investigators recovered some data from the accident vehicle's Mobius OBC, which, when used with the ECM data, provided accident-related information.

The sudden deceleration event threshold for the accident vehicle's Mobius OBC was 7 mph per second. The device reported a generated sudden deceleration event as occurring at 13:19:18 on June 26, 2009. (See appendix C for more information on the vehicle's Mobius OBC.)

Vehicle Braking

The vehicle underwent a postcrash level 1 commercial vehicle inspection conducted by the OHP at the accident scene on June 26, 2009, as well as an NTSB postaccident inspection on June 30, 2009. Although the brake components on the Volvo's steer and second axle were damaged as a result of the accident, examination revealed no preexisting defects. Inspection showed that the brakes were within proper adjustment limits and that all tires possessed the required minimum tread depth.

[17] The Mobius OBC is capable of monitoring vehicle and engine speed when configured to trigger alerts regarding violations of any preconfigured road speed or engine speed thresholds.

Dry pavement skid testing[18] was performed at the accident site on July 1, 2009, at 12:33 p.m. An average friction number of 0.77 longitudinal *g* (acceleration of gravity) at 65 mph[19] was recorded for a passenger car with antilock brakes engaged;[20] thus, this would have been 0.65 longitudinal *g* when accounting for commercial vehicle tires.[21] Therefore, with an air brake lag[22] time of 0.50 second and the Volvo combination unit traveling at about 69 mph with an ABS deceleration rate of -20.93 feet per second/second, the vehicle's stopping distance was 251 feet, plus 51 feet, totaling 302 feet. Thus, if an emergency hard brake application had been made with the accident Volvo truck-tractor semitrailer, which had an unloaded weight of 40,400 pounds, traveling approximately 69 mph with brakes within adjustment limits, the combination unit would have been able to come to a complete stop in approximately 302 feet. This stopping distance does not include the driver's perception or reaction time to initiate vehicle braking.

Driver

The 76-year-old Volvo truck driver had been employed by AWG since 1992,[23] and he possessed a valid Missouri Class "A" commercial driver's license (CDL) with an expiration date of March 20, 2012.[24] Missouri requires that a CDL be renewed every 3 years after a commercial driver turns 70; for drivers under 70, the renewal period is 6 years. The driver also held passenger transportation and doubles/triples trailer endorsements. His license indicated that he was not subject to any restrictions, and he had a current medical certificate, valid for 1 year, with an expiration of December 2009.[25] The NTSB obtained a copy of the driver's Missouri driving history, and it indicated no violations, convictions, or traffic accidents.

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18 A passenger car was used for the testing.

19 A Valentine Research, Inc., g-Analyst accelerometer recorded the information.

20 The test was repeated on the same day at 2:57 p.m. with the antilock brakes disengaged and the test vehicle traveling at 35 mph. The sliding test showed the average deceleration was 0.72 *g*.

21 Because a passenger car was used to conduct the dry pavement skid test, an 85-percent adjustment to this friction value was made to estimate the value for commercial vehicle tires, resulting in a deceleration factor of 0.65 *g*. (See R. Heusser, *Heavy Truck Deceleration Rates as a Function of Brake Adjustment*, SAE paper no. 910126 [Seattle, Washington: National Transportation Safety Board, 1991]).

22 "Air brake lag time" is the time required for a given pneumatic braking system to develop and deliver sufficient air pressure to apply the brakes. Air brake lag times for large commercial vehicles can range from 0.20 to over 1.00 second and may vary greatly due to brake system design, configuration, and mechanical condition, as well as the amount of the required application pressure necessary to achieve the desired level of braking. The 0.50-second estimate used for lag time can be considered under-representative of lag times observed in actual testing of loaded five-axle combination vehicles of typical age and mechanical condition, as published in FMVSS 121. In this case, the 0.50-second lag time provides a suitable level of accuracy, given that the accident vehicle was unloaded, a relatively new model year, and in normal mechanical condition.

23 He had worked for Trailways Bus Lines from 1964 to 1987 and Greyhound Bus Lines from 1987 to 1991.

24 The Federal Motor Carrier Safety Administration (FMCSA) provides a minimum age for commercial drivers (21 years) but not a maximum age.

25 Title 49 CFR 391.45 requires a 2-year examination cycle, unless the examining physician recommends a shorter time period. Previous medical examinations had shown that the driver had borderline high blood pressure, and he was placed on a 1-year reexamination cycle. The driver's medical condition is discussed in the "Driver's Medical Information" section of this report.

When he arrived on scene, the first responding OHP trooper spoke with the accident truck driver, who was still in his vehicle. The trooper subsequently reported that the driver was able to walk and negotiate turns, and he saw no indication of the driver's having visual problems. The OHP accident investigation report stated that the driver was inattentive at the time of the collision.[26]

The driver was subject to postaccident drug and alcohol screening, per 49 CFR 382.303.[27] Urine and blood samples were collected from the driver at the hospital at 5:34 and 7:20 p.m., respectively. The NTSB arranged for a split of the blood specimen collected at 7:20 p.m. under the direction of the Oklahoma State Bureau of Investigation to be tested at the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute toxicology laboratory; the sample was negative for alcohol and a wide range of prescription, over-the-counter, and illicit drugs.[28]

The accident driver refused to be interviewed by NTSB investigators postaccident.

Witnesses' Reports of Driver's Preaccident Actions

The NTSB interviewed several witnesses who were driving on I-44 eastbound and observed the driver and his activities just prior to the accident.

Truck Driver Trainer and Trainee. A truck driver trainer and his trainee student, who was driving a Freightliner tractor with a refrigerated semitrailer, were traveling in the right lane heading eastbound on I-44, and they observed the accident. They saw the Volvo combination vehicle driver pass them in the left lane, traveling approximately 70 mph. They reported that the accident driver changed lanes about a half-truck-length in front of them, without signaling.

The trainer stated that he could observe that traffic ahead on I-44 was stopped, and he told his student to "back down." He recalled that as their vehicle slowed, the Volvo combination unit traveled another 4–5 truck lengths ahead of them; then, the trainer observed debris flying into the air and a vehicle going off the road to the right. The trainer reported not observing brake

[26] The driver was charged with 10 counts of negligent homicide on September 21, 2009. On September 23, 2009, the driver entered a plea of not guilty for all 10 counts. On August 2, 2010, the driver entered a plea of guilty to 10 misdemeanor charges of negligent homicide and was sentenced to 30 days incarceration and 10 years of probation (1 year for each count of negligent homicide). He was also prohibited from possessing a CDL.

[27] Title 49 CFR 382.303, concerning postaccident testing, states that "as soon as practicable following an occurrence involving a commercial motor vehicle operating on a public road in commerce, each employer shall test for alcohol for each of its surviving drivers if the accident involved the loss of human life, if the driver receives a citation within 8 hours of the occurrence under State or local law for a moving traffic violation arising from the accident, or if the accident involved bodily injury to any person who, as a result of the injury, immediately receives medical treatment away from the scene of the accident. If a controlled substance test required by this section is not administered within 32 hours following the accident, the employer shall cease attempts to administer a controlled substances test, and prepare and maintain on file a record stating the reasons the test was not promptly administered." FMCSA guidance states that nothing in the CFR alcohol and controlled substance testing section shall be construed to prohibit a driver from leaving the scene of an accident to obtain necessary emergency medical care.

[28] The examination tested for amphetamine, opiates, marijuana, cocaine, phencyclidine, benzodiazepines, barbiturates, antidepressants, antihistamines, meprobamate, methaqualone, and nicotine.

lights on the accident truck or smoke from the vehicle's tires. After the student driver brought their vehicle to a stop, the two witnesses exited their vehicle and approached the accident truck, which was on top of the passenger vehicles.

The student truck driver reported that while he was driving on I-44, he first noticed the accident truck in his left side mirror, changing from the right into the left lane. He said this occurred about the same time that he began to slow his own vehicle in response to the congestion and brake lights he observed in both lanes ahead of him as he crested the hill. He said he activated his vehicle's four-way flashers when he observed the stopped traffic. He stated that the accident Volvo truck passed him on the left and changed back to the right lane without slowing or braking. The student driver estimated that it took 6–7 seconds for the accident truck to complete the passing maneuver. Then, the Volvo combination unit crashed into the stopped traffic ahead. This witness estimated that his own truck was traveling about 66 mph when he began to brake it and that he had slowed to about 35–40 mph when the accident occurred about 300–400 feet ahead of him. This witness also observed that another truck passed him after the accident Volvo did, and that truck stopped without hitting the traffic queue ahead. This student driver believed that he was able to bring his vehicle to a stop approximately at the location where the Volvo truck had struck the westernmost vehicle in the queue, the Land Rover SUV.

Witness 1 From Left Lane. A witness who had been in the left lane said that when he crested the hill, he observed traffic stopping ahead so he activated his vehicle's four-way emergency flashers. He observed the Land Rover in the right lane and, as both vehicles began slowing, this witness heard a large impact and observed the Volvo truck-tractor strike the Land Rover, which was caught under the bumper and then pushed off to the right. He then saw the Volvo truck run over the other vehicles. He was able to stop his vehicle, and he and his wife attended to the Land Rover occupants until the emergency responders arrived.

Witness 2 From Left Lane. Another witness who was traveling in the left lane told NTSB investigators that as his vehicle crested the hill, it passed the Hyundai sedan. At that time, the Tahoe was in the left lane ahead of him. He noticed that the Tahoe driver put on his four-way flashers. This driver then observed two tractor semitrailers ahead merging to the right, and this allowed him to see farther ahead; he saw that traffic was slowing, so he and the Tahoe began to merge to the right. Before he could execute his lane change, this witness heard a large sound caused by the Volvo truck-tractor striking the passenger cars, and he observed vehicle debris, including the bumper from the Land Rover, which struck his vehicle. He accelerated his vehicle to get out of the way, but the Tahoe still ended up in the left lane ahead of his vehicle. He moved his vehicle around the Tahoe and the Ford F350 pickup truck and livestock trailer and off the side of the road. He then assisted the injured in the Kia.

Chevy Tahoe Driver. NTSB investigators interviewed the driver of the Tahoe involved in the accident. He stated that when he drove over the top of the hill (crest vertical), he observed stopped traffic in the left lane, so he put on his emergency flashers. As he approached the traffic, he began to change lanes to the right in front of the Ford F350 pickup truck (with livestock trailer). Both this driver and his wife heard a crash, and when the driver looked into the rearview mirror, he saw the accident occurring. He said he stepped on the accelerator and steered to the left to try to avoid being struck; however, his vehicle was struck by the Ford F350 and trailer.

F350 Pickup Truck Driver. NTSB investigators also interviewed the driver of the F350 pickup, who stated that he was in the right lane as he crested the hill and could see the stopped and slowing traffic ahead. He glanced in his rearview mirror and observed the Volvo truck-tractor approaching his vehicle. He stated that he was hit just after that. His vehicle then struck the Tahoe in the left lane. He was able to pull his vehicle off to the right shoulder and found that the livestock trailer had become detached from his vehicle and was still partially under the front of the Ford Windstar minivan.

Witness 1 From Traffic Queue. A witness who had been stopped in the traffic queue that resulted from the first accident (involving the Ford Focus) said that he observed in his rearview mirror that a vehicle had been struck from behind and had gone off the road. He then saw a truck strike and run over several more vehicles. He called 911 to report the accident and request ambulances. He exited his vehicle, ran to the accident truck driver, and saw him climb up from the floor of the Volvo cab on the passenger side and sit back into the driver seat.

Witness 2 From Traffic Queue. NTSB investigators interviewed another driver from the traffic queue who did not observe the accident but did interact with the accident driver immediately thereafter. He noticed that both windows of the Volvo truck-tractor were down and that the driver appeared to be disoriented and seemed to have no idea of what had happened.

Driver's Work Shift and Preaccident 72-Hour History

According to AWG, the driver was regularly scheduled to work on Mondays, Thursdays, Fridays, and Saturdays. The driver engaged in shift work;[29] he generally came on duty between 2:00 and 3:00 a.m. and went off duty before 3:00 p.m. He lived about 17 miles from the terminal, and his commute time was about 20–30 minutes. In June 2009, the driver worked a total of 5 days (see figure 7), having been on sick leave for June 6–13 and on preapproved vacation time on June 15 and June 18–20. He worked on June 22 and took a holiday on June 25.[30] He returned to work on June 26, the day of the accident.

[29] "Shift work" is defined as regular employment outside of the normal "day work" hours. See M. Kryger, T. Roth, and W. Dement, *Principles and Practice in Sleep Medicine*, 4th edition (Philadelphia, Pennsylvania: Elsevier-Saunders, 2005), p. 673.

[30] The driver was granted a floating holiday for having worked on Memorial Day.

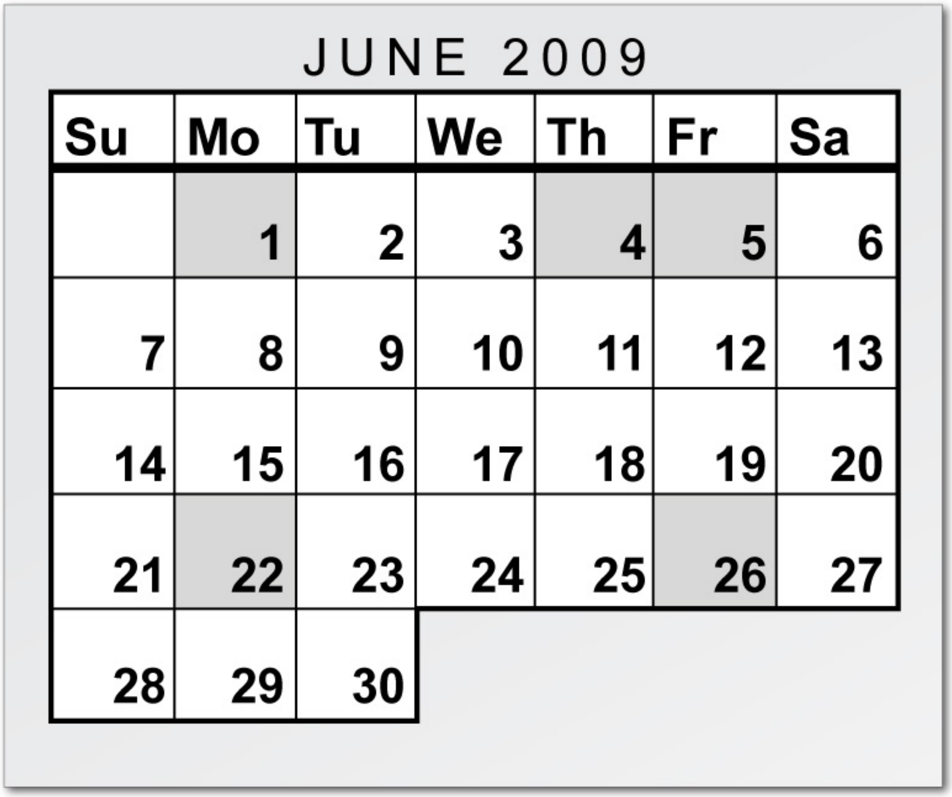

Figure 7. Calendar showing the accident truck driver's daily June 2009 work status (shaded dates indicate the days worked).

The accident driver declined to speak with NTSB investigators; consequently, a full 72-hour history could not be developed.[31] As detailed later in this report, what is known about the driver's sleep–wake schedule comes from a postaccident medical consultation, during which he stated that when he worked, he would try to go to bed about 8:00 p.m. and rise about 12:30-1:00 a.m. The driver also stated that since the accident, he had gone to bed about 10:00 p.m. and risen about 6:00–7:00 a.m. It is unknown whether, when still working, the driver attempted to go to bed at 8:00 p.m. when he was off duty the next day. (Cellular phone records indicate that the accident driver made and received calls about 9:00 p.m. on the nights of Monday, June 22, and Tuesday, June 23, the week of the accident.) Because an accurate account of the driver's sleep-wake schedule could not be reconstructed, this report does not include a standard graphic representation of his work–rest history. Table 3 shows what is known of the driver's activities in the days before the accident, based on witness, cellular telephone, and Mobius OBC information.

[31] Investigators attempted to interview the driver's friends and family members but could not obtain their cooperation. Investigators also attempted to interview neighbors, but none knew the driver well enough to assist in reconstructing a 72-hour history for the driver.

Table 3. Accident truck driver's known activities in the days before the accident, based on witness interviews, cellular telephone records, and Mobius OBC logs. (Note: Cellular telephone records provide the "servicing area" location.)

MONDAY JUNE 22			
5:15 a.m.	Springfield, MO	departed base	Mobius OBC log
6:10	Springfield	received call	phone records
7:40	Mnt Home, AR	arrived	Mobius OBC log
8:26	Mnt Home	departed	Mobius OBC log
8:58	Gainesville, MO	arrived	Mobius OBC log
9:35	Gainesville	departed	Mobius OBC log
10:22	Springfield, MO	received call	phone records
10:30	Springfield	made call	phone records
10:31	Springfield	made call	phone records
10:36	Springfield	received call	phone records
10:55	Springfield	received call	phone records
11:05	Springfield	arrived at base	Mobius OBC log
11:22	Springfield	off duty	Mobius OBC log
8:56 p.m.	Springfield	made call (5 min.)	phone records
TUESDAY JUNE 23			
8:50 a.m.	Springfield, MO	made call	phone records
9:12 p.m.	Springfield	received call (3 min.)	phone records
WEDNESDAY JUNE 24			
7:46 a.m.	Springfield, MO	made call	phone records
7:27 p.m.	Springfield	made call (1 min.)	phone records
THURSDAY JUNE 25			
8:30 a.m.	Springfield, MO	received call	phone records
6:25 p.m.	Springfield	received call (12 min.)	phone records
FRIDAY JUNE 26			
2:30 a.m.	Springfield, MO	arrived at base, preshift	coworker interview
3:00	Springfield	began duty time	Mobius OBC log
3:15	Springfield	departed base	Mobius OBC log
5:45	Chouteau, OK	arrived	Mobius OBC log
6:11	Chouteau	departed	Mobius OBC log
6:45	Muskogee, OK	arrived	Mobius OBC log
7:41	Muskogee	departed	Mobius OBC log
8:24	Vian, OK	arrived	Mobius OBC log
8:51	Vian	departed	Mobius OBC log
9:37	Muskogee, OK	arrived	Mobius OBC log
10:11	Muskogee	departed	Mobius OBC log
10:47	Wagoner, OK	arrived	Mobius OBC log
11:31	Wagoner	departed	Mobius OBC log
11:49	Chouteau, OK	arrived	Mobius OBC log
12:02 p.m.	Tulsa, OK	received call	phone records
12:09	Chouteau, OK	departed	Mobius OBC log
12:46	En route	made call (22 min.)	phone records
1:19	Miami, OK	accident occurred	

When he was scheduled to work, the driver normally began his shift at AWG's Springfield, Missouri, terminal, made deliveries to a number of stores (or other destinations), and returned to the Springfield terminal after completing his final delivery. On the day of the accident, the driver's start time was scheduled[32] for 3:00 a.m., and he left the AWG terminal in Springfield at 3:15 a.m. He traveled to the following destinations (all in Oklahoma): Chouteau, Muskogee, Vian, back to Muskogee, onto Wagoner, and back to Chouteau. The driver departed Chouteau and was headed to the AWG terminal in Springfield when, at 12:46 p.m., while driving on I-44, he began a 22-minute cellular telephone call to a friend. The OHP interviewed the person with whom the accident driver was speaking during this 22-minute telephone call, and that individual stated that the driver was coherent, spoke in a normal fashion, and did not mention anything about being tired or sleepy. The driver ended the telephone call at 1:08 p.m.[33] after remarking that he was in traffic. The accident occurred east of Miami, Oklahoma, about 1:19 p.m., at milepost 321.5. See table 4 for additional information on the driver's activities.

Table 4. Accident driver's locations and travel distances on duty, June 26, 2009.

Location	Departure Time	Destination	Arrival Time	Distance Traveled (miles)[a]	Time Spent at Destination
Springfield, MO	3:15 a.m.	Chouteau, OK	5:45 a.m.	155.4	26 minutes
Chouteau, OK	6:11 a.m.	Muskogee, OK	6:45 a.m.	31.5	56 minutes
Muskogee, OK	7:41 a.m.	Vian, OK	8:24 a.m.	40.4	27 minutes
Vian, OK	8:51 a.m.	Muskogee, OK	9:37 a.m.	40.4	34 minutes
Muskogee, OK	10:11 a.m.	Wagoner, OK	10:47 a.m.	18.0	44 minutes
Wagoner, OK	11:31 a.m.	Chouteau, OK	11:49 a.m.	17.5	20 minutes
Chouteau, OK	12:09 p.m.	Springfield, MO	-------	62.0	*Accident occurs 1:19 p.m. (near Miami, OK)*
[a]Mileage based on PC*Miler for Windows 2000 © ALK Associates, Inc., 1999.					

There is no indication that the driver was engaged in nondriving tasks, such as sending a text message or talking on a citizens band radio or cellular telephone at the time of the accident.[34] Postaccident examination of the roadway and the accident vehicle showed no evidence of braking or evasive steering input by the Volvo truck driver prior to his truck's striking the first passenger vehicle in the traffic queue.

[32] According to AWG, shifts for most of its drivers begin between midnight and 5:00 a.m., with those driving routes to the more distant locations beginning earlier within this time span. Delivery schedules depend on the needs of AWG's customers, who prefer that deliveries arrive before stores open, to allow time for restocking. According to AWG, drivers are not responsible for loading and unloading products during a delivery, but they may assist when needed.

[33] According to AT&T Wireless, the times on its telephone records are based on switch times, which are synchronized with the Official United States Time, as indicated by the National Institute of Standards and Technology atomic clock.

[34] Telephone records indicate a "sent" text or connected telephone call only if the number has been dialed and the signal sent to the cellular tower. If the driver had been in the process of typing a text message or dialing a telephone number into the telephone keypad, the telephone records would not reflect this activity.

NTSB investigators interviewed several of the accident driver's coworkers, who stated that his demeanor was normal on the day of the accident. They stated that he had coffee and socialized with them before beginning his first delivery. One coworker reported having a conversation with the accident driver about 2:30 a.m., before they both started driving. Another coworker told the NTSB that he had seen the driver about 2 days before the accident trip, and he did not notice any sign of illness or emotional issues.

Driver's Medical Information

Medical Certification Examination Information. All CDL drivers are required to undergo medical certification examinations in accordance with the FMCSRs. AWG requires its drivers to undergo these exams. AWG pays for the exams via contract with the Concentra Physical Medicine Institute in Springfield, Missouri. AWG had retained all of the accident driver's medical certification examination "long forms" since 2000. The forms reported that the driver had hypertension and had been taking medication to control the disease since 2005. Drivers with this condition are qualified by regulation to operate a commercial motor vehicle (CMV) if they have "no current clinical diagnosis of high blood pressure likely to interfere with his/her ability to operate a motor vehicle safely" (per 49 CFR 391.41[b][6]).

The driver's 2006 medical certification examination form acknowledged his hypertension and noted that he was taking medication to control both blood pressure and cholesterol. Due to the hypertension, the driver was provided a commercial driver medical certificate that was valid only for 1 year instead of the typical 2-year period. His January 2007 examination form again mentioned the driver's hypertension, and he was certified for another 1-year period.

The driver's form for his January 2, 2008, medical certification examination noted his hypertension, his borderline high blood pressure (his blood pressure was 136/82), and a heart murmur. The Concentra physician conducting this exam requested that the driver undergo an echocardiogram before his next medical certification examination. The driver's personal medical records noted that he underwent a stress echocardiogram on August 27, 2008, and no abnormalities were identified. A Concentra physician performed the driver's next annual exam on December 31, 2008. With respect to certification, the exam report stated, "Meets standards, but periodic evaluation required. Due to Hypertension/Heart; driver qualified for 1 year."

The driver's examination records consistently indicated that he denied having symptoms associated with obstructive sleep apnea (OSA).[35] On each of his three most recent annual Medical Examination Reports for Commercial Driver Fitness Determination, the answer "no" was checked in response to the question concerning "sleep disorders, pauses in breathing while asleep, daytime sleepiness, loud snoring."

[35] OSA is a condition in which a narrowing or closure of the upper airway during sleep causes repeated sleep disturbances and possible complete awakenings, leading to poor sleep quality and excessive daytime sleepiness. (Per <http://www.fmcsa.dot.gov/facts-research/briefs/SleepApneaCrash-RiskStudy-TechBrief.htm> [accessed May 28, 2010].)

At the time of the accident, the driver weighed 240 pounds, was 5 foot 11 inches tall, and had a body mass index (BMI) of 34.4.[36]

Preaccident Hospitalizations. On June 5, 2009, about 3 weeks prior to the accident, the driver went to a hospital emergency room complaining of weakness, diarrhea, and abdominal pain. According to hospital records, he reported that he had experienced "chest pressure, weakness and shortness of breath" and his family indicated that the problems had been going on for "several months." The driver was treated and released but returned on June 8, 2009, with an additional complaint of chest pain. He was hospitalized for 2 days. The medical records further noted that he was a truck driver who drove 400 to 600 miles a day. During the hospitalization, the driver underwent a stress test and echocardiogram with no abnormalities identified. His blood pressure was noted to be low, and he was directed to discontinue his blood pressure medications. The hospital discharge summary stated that the driver self-reported "excessive daytime tiredness and loud snoring at night, raising the possibility of OSA [obstructive sleep apnea]" and that he "prefers to not have evaluation for OSA." He was discharged with an electrocardiographic monitor that he wore for 48 hours. During the monitoring period, he had a large number of abnormal heartbeats but no sustained abnormal heart rhythms.

The hospital discharge medically cleared the driver to return to work on June 14, 2009; his first day back to work and driving was June 22. The driver was then off work on June 23–24 per his usual schedule, during which time he went to the doctor, who noted that the driver's energy was good and that he made no complaints of shortness of breath or chest pain. The driver took another day, June 25, for an in-lieu-of holiday. The accident occurred on June 26, after the driver had been continuously on duty for about 10 hours. This was his second day of driving after his hospitalization.

According to AWG representatives, the accident driver had taken off the week from June 6 through 13 as sick leave, which they believed was due to a stomach virus. AWG representatives stated that they knew the driver had gone to the emergency room after his shift on June 5 complaining of stomach pains, but they were unaware that he had returned to the emergency room on June 8 because of chest pains. The AWG company handbook for employees states that the company has the option of requiring drivers returning from sick leave to submit to a medical examination. AWG did not ask the accident driver to have an examination before returning to work on June 22 after having been on a combination of sick leave and vacation time since June 5.[37]

Postaccident Medical Examinations. After the accident, the driver was admitted to a local hospital for injuries sustained in the accident; he was observed for 24 hours and then released. The driver went to another hospital 2 days later due to markedly elevated blood pressure. During this hospitalization, he was evaluated by a neurologist, who noted the following in the driver's medical record in reference to the accident on June 26,

[36] The U.S. Centers for Disease Control and Prevention define a BMI of 30 or above as constituting obesity. See <http://www.nhlbisupport.com/bmi/> (accessed February 1, 2010).

[37] Specifically, the *Associated Wholesale Grocers Bargaining Unit Employee Handbook* states, "If an employee is absent due to illness or injury, the Company may require a physician's release before reinstatement to the active payroll." The accident driver had been on the active payroll throughout this period.

> He was amnesic for the event. The last thing he remembers was that he saw the traffic was slowing down and he thought he was slowing down in the traffic. But according to the witness, he was not slowing down. The next thing he remembered was that he was out of his truck and a lady was holding his left side of the face. He did not know the exact time that he was out but it was approximately about 15–20 minutes.

A comprehensive inpatient evaluation, including electroencephalogram, magnetic resonance imaging, computed tomography angiogram, and cardiac catheterization, among other studies, did not identify any cause for a loss of consciousness. The neurologist noted "no other evidence to suggest seizures…." The driver's July 2 hospital discharge summary states,

> The patient does not remember and is essentially amnesic of the events of the accident. He remembers that he had slowed down to traffic approaching the scene of an accident and thereafter remembered sitting on the curbside with a nurse helping him.

Prior to his hospital discharge, the driver was told that he "probably has an underlying sleep apnea, and he is counseled yet again with his family members that he needs an outpatient sleep study."

A sleep disorders consult report for the accident driver dated July 27, 2009 (about 5 weeks after the accident), noted that the driver indicated that when he worked, he generally would get to bed about 8:00 p.m. and usually arose about 12:30–1:00 a.m. The driver indicated that "he is now going to bed around 10:00-ish" and would rise about 6:00–7:00 a.m. The driver indicated that he typically fell asleep within a few minutes. The driver reported that he would become sleepy in sedentary situations, typically in his recliner at home reading. The driver's Epworth Sleepiness Scale score was 13.[38] He stated that he generally did not have any trouble driving and would pull over and rest for a few minutes if he felt drowsy. He reported drinking two or three cups of coffee in the morning and an occasional soda, but he reported using no other caffeine sources and denied the use of stimulants, sedatives, or sleeping aids.

The driver underwent a sleep study[39] on August 2, 2009, which demonstrated a short (4 minutes) sleep latency[40] and "mild sleep disordered breathing," with an apnea/hypopnea index of 14 events per hour.[41] The driver's neck circumference was 16 inches.[42] The driver had a second sleep study on August 18, 2009, during which a continuous positive airway pressure (CPAP) mask was applied. While using the CPAP device, the driver demonstrated a sleep latency of 9 minutes 14 seconds, some improvement in sleep architecture, and an

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[38] The Epworth scale is a subjective measure of daytime sleepiness. The scale ranges from 0–24, and scores above 10 are generally regarded as indicating abnormal daytime sleepiness. (M. Johns, "Daytime Sleepiness, Snoring, and Obstructive Sleep Apnea: The Epworth Sleepiness Scale," *Chest,* vol. 103, no. 1 [1993], pp. 30–36.)

[39] The study was conducted at the Sleep Center at St. John's Hospital in Springfield, Missouri, which is accredited by the American Academy of Sleep Medicine. The doctor evaluating the driver was a sleep specialist certified by the American Board of Sleep Medicine.

[40] "Sleep latency" is the time elapsed from when the lights are put out until the first of three consecutive epochs (30 seconds of sleep) of stage 1 sleep, or any other stage of sleep, occurs. (Per *Principles and Practice in Sleep Medicine*, p. 1371.)

[41] Mild OSA is often defined as including apnea/hypopnea index values between 5 and 20 events per hour.

[42] A neck circumference of more than 17 inches in males is associated with an increased risk of OSA.

apnea/hypopnea index of 4.5 events per hour. A post-study note recorded on August 28, 2009, indicated that the driver did not wish to wear a CPAP device in the future due to discomfort.

Motor Carrier Operations

AWG is a cooperative business owned by several chain grocery stores. It is registered with the FMCSA as an interstate common carrier of property.[43] AWG is headquartered in Kansas City, Kansas, with large terminals in Springfield, Missouri, and Fort Worth, Texas, as well as smaller terminals in Goodlettsville, Tennessee; South Haven, Mississippi; and Oklahoma City, Oklahoma. Trucks from the Springfield terminal operate in Arkansas, Illinois, Kansas, Oklahoma, Nebraska, Iowa, Missouri, and Kentucky. At the time of the accident, the Springfield terminal employed 131 drivers and operated about 100 truck-tractors.

Each AWG driver was assigned to a specific truck-tractor for all shifts and scheduled trips. Of the 131 drivers employed from Springfield, 40 were assigned to overnight trips, and the remaining drivers were assigned to daily trips. The company operates 7 days per week, 24 hours per day. AWG reported that company drivers bid for shifts, based on seniority, three times per year; the drivers operated on their assigned schedule for 4 months at a time. According to AWG, the accident driver had been operating on the same schedule since at least 1997. AWG reported that shifts for most of its drivers began between midnight and 5:00 a.m.; the shifts for drivers delivering to more distant locations began earlier within that timeframe.

Driver Training

AWG provided recurrent training on an annual basis to its drivers. Each driver attended a training session once a year that consisted of viewing video presentations and taking associated quizzes; the driver had to score 100 percent on the quizzes to pass. The accident driver attended the training sessions every year and completed the quizzes.[44] Other communications for the drivers were provided via a bulletin board and notices given directly to the drivers.

Among AWG's training materials was a videocassette titled, "The Alert Driver: A Trucker's Guide to Sleep, Fatigue, and Rest in Our 24-Hour Society," published by the American Trucking Associations, Inc. (ATA), in coordination with the Federal Highway Administration (FHWA) Office of Motor Carriers (this agency later became the FMCSA), in 1996. The video was accompanied by a booklet that expanded on themes in the video. Apart

[43] "Property" includes general freight, household goods, fresh produce, meat, refrigerated food, beverages, and paper products.

[44] According to AWG, the driver was up to date with his training. On June 4, 2009, the driver had passed an on-line interactive training program on safe truck backing procedures. AWG selects the videos that the drivers watch. Drivers are required to view all the videos before they review any that they have already seen. The exception is if a driver is having a specific problem that AWG wants them to address. Under such circumstances, a driver might have to repeat a video.

from showing its drivers the video, AWG did not have a formal or written fatigue management program.[45]

Cellular Telephone Use Policy

AWG's policy regarding personal cellular telephone use appears in its employee handbook.[46] It states, "The use of cellular telephones can lead to workplace distractions that can cause the user to put themselves or others in dangerous situations." The handbook further states, under *Prohibited Use*, that "Employees will not use or carry their cellular telephone in any fashion while performing their jobs."[47] The NTSB obtained the accident driver's cellular telephone records. The records for June 22 showed that the driver had used his personal cellular telephone that day when driving the company's Volvo combination unit.[48]

The records for June 26 (the day of the accident) indicated that he used his personal cellular telephone while driving and while in "on-duty, not driving" status during his shift. On June 26, the driver arrived at his destination of Chouteau, Oklahoma, at 11:49 a.m. and received a call at 12:02 p.m. He departed Chouteau 7 minutes later, at 12:09 p.m. He then placed a call while driving on I-44 at 12:46 p.m.; this call lasted for 22 minutes, until 1:08 p.m.

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[45] A fatigue management program is a system developed to address the problems associated with fatigue in a particular operating environment. Such a program is designed to take an all-inclusive, customized approach to addressing fatigue in that environment. It typically includes components such as means of addressing the following factors within a company: scheduling policies and practices; attendance policies; employee education, medical screening, and treatment; personal responsibility while off work; task/workload issues; rest environments; and commuting and napping policies. It should also include means of implementing, supervising, and evaluating the program.

[46] *Associated Wholesale Grocers Bargaining Unit Employee Handbook, Springfield Division*, "Policies and Procedures," October 4, 2009, p. 5.

[47] Nine states (California, Connecticut, Delaware, Maryland, New Jersey, New York, Oregon, Utah, and Washington), the District of Columbia, and the U.S. Virgin Islands have laws that prohibit all drivers from using handheld cellular telephones while driving. Except for the laws in Maryland and Utah, these are primary enforcement laws, meaning that a police officer may cite the driver for using the handheld cellular telephone without any other traffic offense taking place. In Utah, the offense is termed "careless driving"; under Utah law, careless driving is committing a moving violation (other than speeding) while distracted by use of a handheld cellular telephone. No state bans all cellular telephone use (handheld and hands-free) for all drivers. Thirty states, the District of Columbia, and Guam ban text messaging by all drivers. Twenty-six states, the District of Columbia, and Guam have primary enforcement for their texting ban laws, while in the other four states, the bans have secondary enforcement. Currently, Oklahoma permits handheld and hands-free cellular telephone use by drivers with the following exceptions—novice drivers are banned from using handheld cellular telephones (unless in a life-threatening emergency), and school bus and public transit drivers are banned from all cellular telephone use while driving. Oklahoma does not ban drivers from texting, with the exception of prohibiting texting by novice, school bus, and public transit drivers. Oklahoma has a preemption law that prohibits localities from enacting such bans on drivers. (Source: <http://www.nhlbisupport.com/bmi/> and <http://www.ghsa.org/html/stateinfo/laws/cellphone_laws.html> [both accessed September 13, 2010.])

[48] On Monday, June 22, while working his shift, the driver received a call at 6:10 a.m., received a call at 10:22 a.m., made a call at 10:30 a.m., made a call at 10:31 a.m., received a call at 10:36 a.m., and received a call at 10:55 a.m. That day, the driver arrived back at the Springfield, Missouri, AWG base facility at 11:05 a.m. and went off duty at 11:22 a.m., according to the Mobius OBC logs.

Postaccident Compliance Review

According to the FMCSA's Safety and Fitness Electronic Records database, AWG had been the subject of 129 inspections in the 24 months prior to July 1, 2009, including 75 vehicle inspections and 128 driver inspections.[49] These resulted in 17 vehicle out-of-service (OOS) violations (22.70 percent) and no driver OOS violations. The national vehicle OOS rate for calendar years (CY) 2007 and 2008 was 22.30 percent; it was 21.22 percent for CY 2009. The national driver OOS rates for CY 2007, 2008, and 2009 were 6.80 percent, 6.40 percent, and 5.60 percent, respectively.

Prior to the accident, the most recent compliance review of AWG had been conducted 15 years earlier, on April 20, 1994, and at that time, the company received a satisfactory rating.[50] Postaccident, on July 15, 2009, the FMCSA conducted a compliance review of AWG that resulted in a conditional rating. (See appendix D for FMCSA postaccident compliance review violations.) The conditional rating was due to a violation of 49 CFR 382.215, using a driver known to have tested positive for a controlled substance—an acute violation—and a violation of 49 CFR 382.301(a), using a driver before the motor carrier had received a negative preemployment controlled substance test result—a critical violation.[51] AWG has not had any additional compliance reviews, and as of September 21, 2010, its safety rating was satisfactory.[52]

Other Information

Highway Design for Sight Distance and Stopping Sight Distance

AASHTO defines "sight distance" as the length of the roadway ahead that is visible to the driver and is sufficiently long to enable a vehicle traveling at or near the design speed of the

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[49] Total inspections are less than the number itemized (such as driver or vehicle) because driver and vehicle categories are counted twice when each level of inspection is conducted at the same time. There are seven "levels" (or categories) of roadside inspection. *Level 1* includes the driver and vehicle (including an inspection of the components on the undercarriage, such as brake adjustment); *level 2* is a driver and vehicle walk-around inspection (does not include an inspection of the vehicle's undercarriage components); *level 3* is a driver/credential inspection only; *level 4* is a special investigation, typically including a one-time examination of a particular item, and is normally conducted in support of a study or to verify or refute a suspected trend; *level 5* is a vehicle-only inspection; *level 6* is a Transuranic Waste and Highway Route Controlled Quantities of Radioactive Materials inspection; and *level 7* is a jurisdiction-mandated commercial vehicle inspection.

[50] Safety ratings are provided as follows: A *conditional* rating means that a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard that could result in occurrences listed in 49 CFR 385.5 (a) through (k); a *satisfactory* rating means that a motor carrier has in place and functioning adequate safety management controls to meet the safety fitness standard prescribed in 49 CFR 385.5; and an *unsatisfactory* rating means that a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard, which has resulted in occurrences listed in 49 CFR 385.5 (a) through (k).

[51] Title 49 CFR Part 385 describes the rating system for carriers. Selected regulations are classified as *acute* or *critical*. An acute violation occurs when noncompliance is so severe as to require immediate corrective actions. One acute violation can adversely affect the carrier's safety rating. A critical violation is one that indicates a breakdown in safety management and/or operational controls. To affect a carrier's safety rating, there must be a pattern of violation, consisting of 10 percent or more among the records checked.

[52] See <http://safer.fmcsa.dot.gov/query.asp#Inspections > (accessed September 21, 2010).

roadway to stop before reaching a stationary object in its path.[53] "Stopping sight distance" is defined as a sum of two distances: (1) the distance traversed by the vehicle from the instant the driver sees an object necessitating a stop to the instant that the brakes are applied, and (2) the distance needed to stop the vehicle from the instant brake application begins. These distances (1 and 2) are referred to as "brake reaction time" and "braking distance," respectively.

Vehicle braking is dependent on the driver's brake reaction time and the vehicle braking efficiency. Brake reaction time (see [1] above) includes the time it takes for the driver to see the object and to recognize it as stationary or slow-moving against the background of the roadway and other objects, such as walls, fences, trees, poles, bridges, etc. The brake reaction time can vary per driver/situation, dependent on the driver's visual acuity, the driver's natural ability to react quickly, the atmospheric visibility, and the condition of the roadway.[54] Brake reaction times may vary considerably among drivers; AASHTO considers minimum brake reaction times to be between 1.64 and 3.50 seconds. The recommended design criterion of 2.50 seconds for brake reaction time exceeds the 90th percentile of reaction time for all drivers. The 2.50-second criterion is considered adequate for conditions more complex than simple situations used in laboratory and road tests.[55]

Heavy Commercial Vehicle Crash Data

General. In March 2010, the FMCSA released data from the 2008 *Large Truck Crash Overview*, in which it reported that, of the 37,261 people killed in motor vehicle crashes in 2008, about 11 percent (4,229) died in crashes that involved a large truck.[56] Another 90,000 people were injured in crashes involving large trucks. Eighty-four percent of those killed and 74 percent of those injured in such crashes were not the occupants of large trucks.[57] The most commonly cited factors for drivers of large trucks involved in crashes were failing to keep their lanes properly (11 percent), driving too fast (8 percent), and being inattentive (6 percent).

In September 2010, NHTSA released the 2009 Fatality Analysis Reporting System (FARS) data, in which it reported that, of the 33,808 people killed in motor vehicle crashes in 2009, 10 percent (3,380) died in crashes that involved a large truck.[58] The 2009 injury data for large truck crashes are not yet available, but there is known to have been a 26-percent reduction in the number of injuries in large truck crashes between 2009 and 2008. Eighty-five percent of those killed in 2009 were not the occupants of the large trucks involved.

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[53] *A Policy on Geometric Design of Highways and Streets*, 5th edition (Washington, DC: American Association of State Highway and Transportation Officials, 2004), p. 110.

[54] *A Policy on Geometric Design of Highways and Streets*, p. 110.

[55] *A Policy on Geometric Design of Highways and Streets*, p. 111.

[56] With respect to this data, a "large truck" is a truck with a GVWR greater than 10,000 pounds (includes medium and heavy trucks).

[57] See <http://www.fmcsa.dot.gov/facts-research/LTCO2008/2008LargeTruckCrashOverview.aspx> (accessed May 13, 2010).

[58] See <http://www-nrd.nhtsa.dot.gov/Pubs/811363.pdf> (accessed September 16, 2010).

Large Trucks Rear-Ending Passenger Vehicles. In the most recent 9-year span of data available from NHTSA's FARS, for 2001 to 2009, there were 7,186 passenger vehicle fatalities in 2-vehicle rear-end crashes; 1,453 of these fatalities occurred in accidents involving a large truck rear-ending a passenger vehicle(s).When passenger vehicle occupants died in rear-end collisions involving three or more vehicles, large trucks were involved in an average of 34 percent of these fatalities. (See table 5.)

Table 5. Passenger vehicle[a] fatalities in rear-end collisions (FARS data).[b]

Number/Vehicle Type Involved	2009	2008	2007	2006	2005	2004	2003	2002	2001	Total
2 vehicles	579	630	779	815	857	869	869	903	885	7,186
2 vehicles, large truck involved	94	123	164	174	178	165	191	176	188	1,453
Percent of fatalities; 2 vehicles, large truck involved	16%	20%	21%	21%	21%	19%	22%	19%	21%	20% (avg.)
3 or more vehicles	343	393	483	505	514	488	582	509	538	4,355
3 or more vehicles, large truck involved	130	145	187	189	181	208	147	126	160	1,473
Percent of fatalities; 3-or- more vehicles,large truck involved	38%	37%	39%	37%	35%	43%	25%	25%	30%	34% (avg.)

[a]For purposes of this table, "passenger vehicles" are defined as cars, minivans, SUVs, and pickup trucks.

[b]Rear-impact collisions among passenger vehicles were coded if either their principal or initial impact points were coded as 5, 6, or 7 o'clock. This indicates both fatal crashes in which major damage was to the vehicle rear and fatal crashes in which initial impact was to the rear of the vehicle (the initial impact presumably started the chain of events leading to a passenger vehicle occupant fatality). Large trucks in these collisions were coded as involved if their principal points of impact were 11, 12, or 1 o'clock. If large trucks' principal points of impact were missing, their initial impact points were substituted.

North American Fatigue Management Program

For the past several years, the FMCSA has been working with Canadian regulators and industry associations to develop a comprehensive approach to managing fatigue in a motor carrier operating environment. Termed the North American Fatigue Management Program (NAFMP) for commercial motor carriers,[59] 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.[60] The final product of this effort is expected to comprise several components considered necessary to managing driver fatigue, including the following items:

- Corporate change processes, including the involvement and support of management,
- Modifications to scheduling policies and practices,
- Companywide fatigue management training,
- Sleep disorder screening and treatment for drivers, and
- Fatigue-monitoring technologies and alertness strategies.

Work on the NAFMP began in 1999, when the AMTA contracted with the Canadian Sleep Institute to undertake a study to develop and field test an integrated fatigue management program for CMV drivers. In 2000, a steering committee with representatives from AMTA, Alberta Transportation, Transport Canada, and the FMCSA assumed overall management of the effort.[61]

Phase I of the NAFMP took place in 2000 with a series of focus groups consisting of drivers, dispatchers, and managers, who assisted in the project design. The focus groups identified subjective and objective tools for use in data collection, and a beta test with six drivers was undertaken.[62] Phase II of the NAFMP, completed in January 2006, involved the development of fatigue-related educational and training materials, the development and

[59] Per the Canadian Council of Motor Transport Administrators *Request for Proposal for the Development of Guidelines and Materials to Enable Motor Carriers to Implement a Fatigue Management Program*, Ottawa, Ontario, May 3, 2010.

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

[61] The steering committee now includes representatives from Transport Canada, the FMCSA, Alberta Transportation, the Alberta Workers Compensation Board, Alberta Employment and Immigration, the Société de l'Assurance Automobile du Québec, the Commission de la Santé et de la Sécurité du Travail du Québec, the Canadian Trucking Alliance, the AMTA, the American Transportation Research Institute, and the Quebec Trucking Association.

[62] A. Moscovitch and others, *Development of a North American Fatigue Management Program for Commercial Motor Carriers: Phase II (Pilot Study)*, TP 14828E (Ottawa, Ontario: Transport Canada, January 2006), pp. vii–xvi.

assessment of procedures for field testing, and the execution of actual field tests in Quebec, Alberta, and Texas.[63] Phase III, completed in September 2009, was a field study of a comprehensive fatigue management program among carriers in Quebec, Alberta, and California. The program involved (1) educational sessions at all levels of the trucking company, (2) sleep disorder diagnosis and treatment, and (3) interaction with dispatchers and management to improve dispatch practices with regard to fatigue. The goal of the 2009 field test was to assess the feasibility of a companywide approach to fatigue management and its impact on drivers' fatigue, performance, sleep duration, and mood, as well as on company performance measures and scheduling policies and practices. The results from phase III were generally positive, with drivers reporting improvements in sleep length/quality and fewer critical events (nodding off and close calls). During the 3-month testing period, companies in Quebec reported significantly fewer road infractions and accidents, and fewer days of driver absenteeism, but this trend did not reach significance in California or Alberta.[64]

The final phase of the NAFMP is to include the creation of motor carrier guidelines, tools, training materials, performance indicators, policies, practices, and procedures for the design and implementation of an effective fatigue management program. The NAFMP products will take into account the most current research on corporate culture, education and training, sleep disorder screening and treatment, scheduling, and fatigue-monitoring technologies. The guidelines will be designed to apply to all motor carriers, regardless of the size of the operation. The Canadian Council of Motor Transport Administrators published a request for proposal for the final phase of the NAFMP in May 2010, and numerous proposals for completing the project have been received. According to one NAFMP official,[65] the fatigue management program guidelines are expected to be completed within the next 2 years.

Forward Collision Warning Systems

Collision warning systems (CWS), also known as collision avoidance systems or forward collision warning systems (FCWS), are vehicle-based electronic systems that monitor the roadway in front, and in some applications to the side, of the host vehicle and warn the driver of a potential collision risk. FCWSs are designed to alert drivers to an impending collision with an object in their forward path, which may allow them to respond to such a situation sooner, and thus reduce the impact speed or allow them to avoid the crash altogether.[66]

FCWSs are available from the original vehicle manufacturer and are often sold within an optional safety package that includes other safety systems such as lane departure warning, active braking, ESC, ABS, and fleet management programs (which may provide feedback for driver

[63] A. Moscovitch, TP 14828E.

[64] A. Smiley and others, *Effects of a Fatigue Management Program on Fatigue in the Commercial Motor Carrier Industry: Summary Report*, TP 14921E (Ottawa, Ontario: Transport Canada, September 2009), p. vii.

[65] Per correspondence from the executive director of the Vehicle Safety and Carrier Service of the Ministry of Transportation of the Government of Alberta, Canada.

[66] H. Rakha and others, "Safety Benefit Evaluation of a Heavy Vehicle Forward Collision Warning System," paper 10-0207, presented during the January 10–14, 2010, Transportation Research Board 89th Annual Meeting in Washington, D.C.

behavioral programs using on-board recorders with GPS and HOS functions). An FCWS can also be purchased as an aftermarket option, meaning that the product can be retrofitted to the vehicle.

Most FCWSs use radar technology mounted to the vehicle, typically within the front bumper assembly. When other vehicles or stationary objects come within predefined distances or closing speeds in the forward path of the host vehicle, audible and visual alerts are communicated to the driver from an in-cab display unit. One add-on to this system is adaptive cruise control (ACC), which uses the same technology to adjust or disengage conventional cruise control if it is in use when a collision risk is detected. Some FCWSs can also engage vehicle braking when an imminent hazard is detected; this is called “active braking” or collision mitigation braking (CMB). When combined with FCWSs, such systems are often called collision mitigation systems.

For heavy vehicles, usually large trucks and buses, FCWSs currently on the market rely on Doppler-based radar that transmits and receives signals to determine vehicle-to-vehicle distance, differences in relative vehicle speeds, and the azimuth between the large truck and the vehicle or object in front of it.[67] The system’s beam width/field of view forms a triangle with its apex at the front center of the host vehicle. When a heavy vehicle equipped with an FCWS approaches a slower moving vehicle or stationary object, the system issues progressively more urgent warnings, according to preset thresholds (such as a minimum 3.00-second following distance designed to improve driver behavior). (See figure 8.)

[67] *Analysis of Benefits and Costs of Forward Collision Warning Systems for the Trucking Industry*, FMCSA-RRT-09-021 (Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, February 2009), p. v.

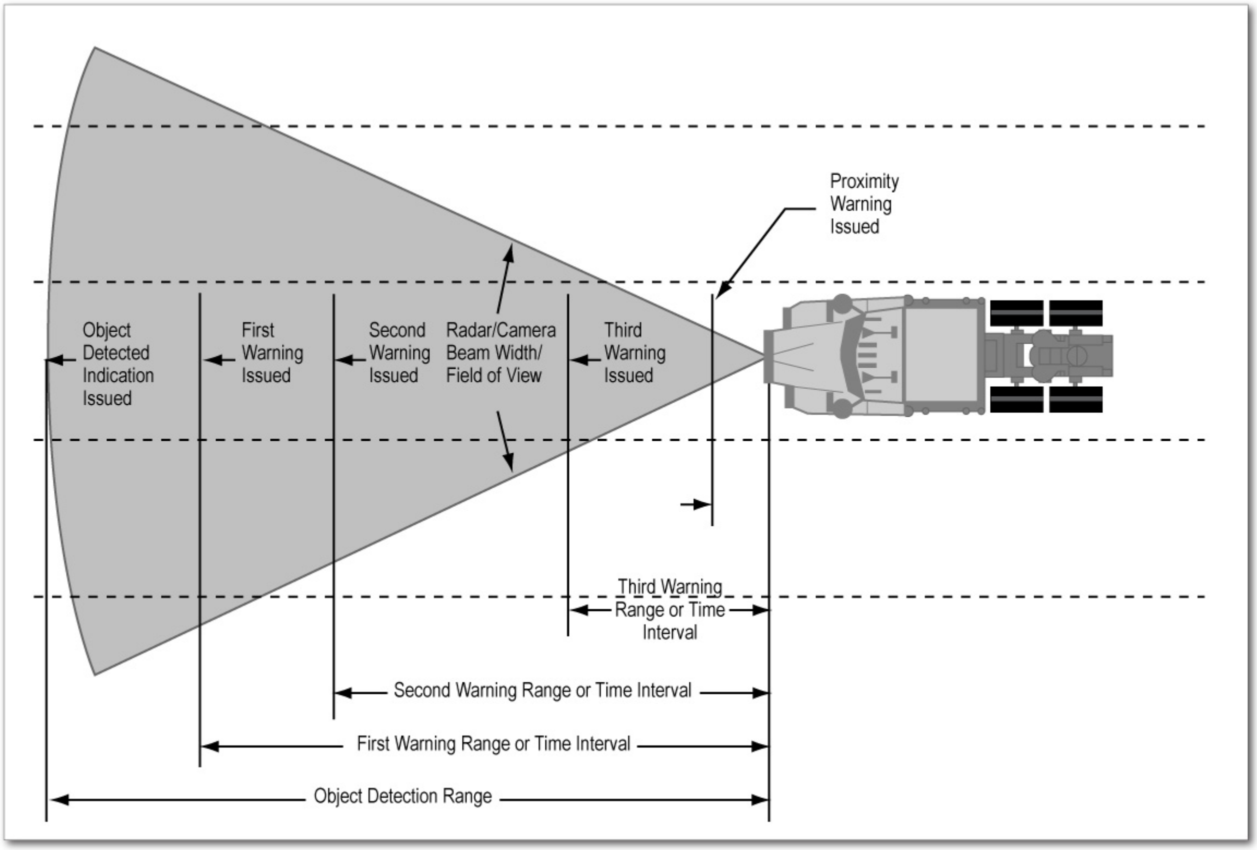

Figure 8. FCWS object detection and warning thresholds. [Original source figure, adapted by the NTSB, obtained from the FMCSA.[68]]

Some currently available systems can detect and display warnings at a distance of 350 feet or a following distance period of up to 3.00 seconds. A "collision alert" warning occurs if the following distance closes to less than 0.50 second or the radar detects slow-moving or stopped traffic within 350 feet of the vehicle, at which time the system alerts the driver with three red LED indicators and an audible tone.

In February 2005, Volvo Trucks North America published a study titled *Volvo Trucks Field Operational Tests (FOT): Evaluation of Advanced Safety Systems for Heavy Truck Tractors*; Volvo conducted the study for the DOT, as part of the Department's Intelligent Vehicle Initiative (IVI). The FHWA sponsored an FOT involving large trucks to evaluate the viability of rear-end CWSs, as well as ACCs and electronically controlled brake systems. The trucks were organized into 3 fleets: 20 baseline trucks with the FCWS display disabled, 50 new tractors built to U.S. Xpress[69] fleet standard specifications with FCWS alone, and 50 new

[68] See <http://www.fmcsa.dot.gov/facts-research/research-technology/report/forward-collision-warning-systems.htm> (accessed June 7, 2010).

[69] U.S. Xpress Enterprises, Inc., is a long-haul regional transportation company based in Tennessee. U.S. Xpress was established in 1986 and it employs about 8,000 people.

tractors equipped with bundled advanced safety systems. Those vehicles with the bundled systems were equipped with FCWSs, ACCs, and disc brakes with electronically controlled brake systems. The two study groups comprising 100 new tractors were operated within the U.S. Xpress national fleet in commercial revenue-generating service and were operated over a 3-year period, beginning in 2001.[70,71] Two separate reports published in 2007, based on the 2005 field test, reported a 28-percent reduction in rear-end crashes as a result of the FCWSs, ACCs, and brake systems bundled together and a 21-percent reduction from the FCWSs alone. It was projected that if FCWSs had been deployed to the entire U.S. truck-tractor semitrailer fleet (consisting of about 1.8 million vehicles), the bundled advanced systems could have prevented an estimated 6,500 rear-end crashes, 3,400 injuries, and 122 fatalities per year. It was also projected that equipping the same 1.8 million vehicles with FCWSs alone could have prevented 4,700 rear-end crashes, 2,500 injuries, and 96 fatalities each year.[72]

FCWSs provided a significant reduction of rear-end collision risk by allowing more time for the driver to react to high-risk, fast-closing situations. FCWSs reduced the risk of crashes with vehicles ahead because braking generally occurred earlier in the conflict for trucks with FCWSs than for trucks without such systems. Additionally, drivers usually adopted longer following-distance driving behaviors while using FCWSs. The results of the Volvo FOT indicated that advanced safety systems provide improved safety in rear-end collisions and that the systems are ready for commercial deployment.

In July 2005, the FMCSA published *Concept of Operations and Voluntary Operational Requirements for Forward Collision Warning Systems and Adaptive Cruise Control Systems On-Board Commercial Motor Vehicles*.[73] It established voluntary operational requirements for the features and functions of FCWSs and ACC systems. Among the items included are that the FCWS should be able to detect, track, and issue warnings for potential precollision conditions based on following interval thresholds when the host vehicle is closing on a vehicle that is accelerating, decelerating, has a constant velocity, has just changed lanes, or is stopped. The FMCSA voluntary requirements also noted that FCWSs and ACC systems should be capable of detecting a vehicle in the same travel lane at a distance of up to 328 feet on straight roads.

In February 2009, the FMCSA published a report[74] summarizing several benefit-cost analyses that were conducted in an effort to accelerate voluntary adoption of on-board safety

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

[71] The FCWS used in the IVI study was the Eaton VORAD EVT-3000.

[72] (a) *Final Report, Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version 1.3, January 5, 2007*, by Battelle (Columbus, Ohio: 2007) for the DOT, contract DTFH61-96-C-00077, task order 7721. (b) M. Lehmer and others, "Volvo Trucks Field Operational Test: Evaluation of Advanced Safety Systems For Heavy Trucks," paper 07-0212, p. 6, in the proceedings of the 20th International Technical Conference on Enhanced Safety of Vehicles held June 18-21, 2007, in Lyon, France <http://www-nrd.nhtsa.dot.gov/pdf/esv/esv20/07-0212-W.pdf> (accessed July 20, 2010).

[73] See <http://www.fmcsa.dot.gov/facts-research/research-technology/report/forward-collision-warning-systems.pdf> (accessed July 20, 2010).

[74] *Benefit-Cost Analyses of On-Board Safety Systems, Analysis of Benefits and Costs of Forward Collision Warning Systems for the Trucking Industry*, FMCSA-RRT-09-023 (Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, February 2009).

systems, including FCWSs.[75] Five years of crash data, from 2001 to 2005, in the General Estimates System were used to estimate the average annual numbers of crashes preventable by each of the three different systems.[76] Using efficacy rates of 21 percent and 44 percent, it estimated that 8,597 to 18,013 rear-end crashes might have been prevented from 2001 through 2005 by the use of FCWSs in the trucking industry.

The FMVSSs, which are issued by NHTSA, establish the minimum performance requirements for motor vehicle safety systems and components. NHTSA also regulates the manufacture of motor vehicles to ensure compliance with the FMVSSs. NHTSA is addressing FCWSs in its Crash Avoidance Research Program, which includes the DOT's integrated vehicle-based safety systems (IVBSS) initiative, which is studying lane departure warning, lane change warning, and curve speed warning systems. Through the IVBSS initiative, the DOT established a partnership with the automotive and commercial vehicle industries to develop and field test an integrated safety system on light vehicles and commercial trucks.

In November 2005, the DOT entered into a cooperative research agreement with a private consortium led by the University of Michigan Transportation Research Institute (UMTRI) to build and field-test an IVBSS designed to prevent rear-end, lane change, and run-off-road crashes.[77] The IVBSS research initiative seeks to accelerate the introduction and commercialization of integrated vehicle-based crash warning systems for light vehicles and heavy trucks.[78] During the first 2 years of the program, the industry team designed, built, and conducted tests to verify the prototype systems on passenger cars and heavy trucks. The prototype vehicles underwent a series of closed-course track tests aimed at ensuring that the integrated system met the performance requirements and was safe for use by unescorted volunteer drivers during the FOT, which was planned for phase II of the effort. Approval to proceed with phase II of the program was granted on April 8, 2008. According to the DOT's Research and Innovative Technology Administration (RITA), 10 IVBSS-equipped International ProStar 8600-series trucks owned and operated by Conway Freight, Inc., of Ann Arbor, Michigan, participated in the field test. The heavy truck field test began in February 2009 and was completed on December 15, 2009. The trucks were driven by 20 volunteer drivers for Conway's regular pickup, delivery, and line haul routes over the 10-month period, amassing 16,500 hours of driving time. Approximately 650,000 miles of driving data were collected; 140,000 miles consisted of baseline data, and 510,000 miles of data were recorded with the integrated system enabled.[79]

[75] The benefit-cost analysis report was to provide the motor carrier industry return-on-investment information to encourage purchase of on-board safety systems. The potential benefits, in terms of crash cost avoidance, were measured against the cost of technology purchase, installation, and operation.

[76] See <http://www.fmcsa.dot.gov/facts-research/research-technology/tech/09-023-TB-On-board-Safety-Systems-508.pdf> (accessed June 28, 2010).

[77] See <http://www.its.dot.gov/ivbss/index.htm> (accessed June 25, 2010).

[78] See <http://www.rita.dot.gov/publications/horizons/2009_05_01/html/vehicle_safety_systems.html> (accessed June 25, 2010).

[79] See <http://www.its.dot.gov/ivbss/index.htm> (accessed September 21, 2010).

The DOT has received UMTRI's report on the FOT. UMTRI and the Transportation Research Board released the report in August 2010. NHTSA is expected to release the report publicly in fall 2010.

Crashworthiness

The term "crashworthiness" refers to how well a vehicle's structural design withstands a collision and maintains adequate survivable space for occupants. Crashworthiness is dependent on many factors, including the compatibility of the impacting vehicles, the structural design of the vehicles, the materials used for vehicle construction, and the methods of energy management used for occupant protection. For two vehicles to be considered "compatible" in a crash, three factors—vehicle weight, vehicle structure stiffness, and vehicle design geometry—should be reasonably comparable.

If vehicle weight, structure stiffness, and geometry vary dramatically between two impacting vehicles,[80] such as when a larger and heavier commercial vehicle strikes a smaller and lighter passenger vehicle, then the vehicles will not be compatible. The larger and heavier commercial vehicle is termed to have "high aggressivity" in this type of impact, because the passenger vehicle will most likely absorb more of the impact energy, either through structural crush, overlap and override, or large accelerations from impact.

In April 2000, the 21st Century Truck Partnership (21CTP) was announced at a gathering of representatives of U.S. truck and supporting industries, environmental entities, and Federal agencies, including the U.S. Department of Energy (DOE) and the DOT. This partnership released a "roadmap" for developing viable technologies for the improvement of safety in the nation's trucking industry.[81] One of the many goals and research objectives of the 21CTP is to improve truck and bus safety by fostering advancements in vehicle design and performance, such as reducing the frontal aggressivity of trucks in multivehicle collisions.[82,83]

In 2003, the European Union and the United Kingdom Department for Transport (DfT) sponsored a 3-year project called the *Improvement of Vehicle Crash Compatibility Through the Development of Crash Test Procedures* (VC-COMPAT).[84] The primary objectives of the VC-COMPAT project were as follows:

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[80] S. Acierno and others, "Vehicle Mismatch: Injury Patterns and Severity," *Accident Analysis and Prevention*, vol. 36 (2004), p. 761.

[81] See <www.dieselnet.com/news/2001/01doe2.php> (accessed June 10, 2010).

[82] 21st Century Truck Partnership, *Roadmap and Technical White Papers*, 21CTP-001 (Washington, DC: U.S. Department of Energy, December 2000), p. 4-17.

[83] According to the 2000 technology roadmap, the milestone for improving crashworthiness—including the completion of laboratory tests and field trials of systems to reduce the destructive effects of accidents—was mid-2009.

[84] *DfT Support for VC-COMPAT Final Report* (Cranfield Impact Centre Ltd., report 572), pp. 3–5.

- Conduct analysis of trucks and trailers,
- Create a database of heavy goods vehicles,
- Provide a report on current underride devices, and
- Consider the use of numerical modeling as an alternative to car–truck front underride testing.

One of the first VC-COMPAT project undertakings was an analysis of how its approved rigid front underride protection systems (FUPS)[85] compared to other available devices, which included an energy-absorbing FUPS. Results from the 2006 VC-COMPAT indicated that about 11 percent of fatally and 30 percent of seriously injured car occupants could be saved if trucks were equipped with energy-absorbing FUPSs instead of rigid FUPSs.[86]

In 2006, the 21CTP published another *Roadmap and Technical White Papers*,[87] which announced the 21CTP objective to work collaboratively with DOT-led research programs to enhance the crashworthiness of large trucks. Specifically, the goal is to determine the feasibility of enhanced occupant survivability in collisions (offset, frontal, and angle/sideswipe) at differential speeds up to 35 mph between heavy vehicles and passenger vehicles weighing approximately 4,000 pounds. Several potential technologies were listed as elements of achieving the goal, as follows:

- Development of crash energy management technologies,
- Creation of vehicle structural system design and under-run barriers, and
- Achievement of advances in crash attenuation material technologies.

Crash energy attenuation and management focus on reducing the kinetic energy of crash forces through the reduction of aggressivity, which may be achieved by incorporating crash-absorbent material in crash-critical structural elements and by designing and implementing crash deflectors. The long-term focus is on developing dynamic performance measurements for improving crash attenuation, incorporating crash-resistant and crash-absorbent material designs, reducing vehicle mass disparities, and minimizing geometric mismatches. The near- and long-term goals for structural systems design efforts are the development and incorporation of advanced materials in vehicle structural systems, with specific consideration of how to develop crashworthy vehicle geometry and crash-protected front-and-rear designs, as well as of how to enhance stiffness dispersion.

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[85] Per Economic Commission for Europe (ECE) Regulation 93, Part I, "Uniform Provisions Concerning the Approval of Front Underrun Protection Devices." For additional information, see <www.unece.org/trans/main/wp29/wp29regs.html?expandable=0&subexpandable=0> (accessed June 10, 2010).

[86] *DfT Support for VC-COMPAT Final Report*, p. 6.

[87] 21st Century Truck Partnership, *Roadmap and Technical White Papers*, 21CTP-0003 (Washington, DC: U.S. Department of Energy, December 2006). For additional information, see <http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/21ctp_roadmap_appendix_2007.pdf> (accessed August 10, 2010).

Significant Government and Industry Efforts on Event Data Recorders

In 2000, NHTSA organized the Truck and Bus EDR Working Group to focus on data elements, survivability, and event data definitions related to trucks, school buses, and motorcoaches. The group's results and findings, which defined data variables, survivability requirements, and event trigger guidelines, were published in May 2002.[88] The working group also noted that U.S. and European studies have shown that the number and severity of crashes are reduced when drivers know that an on-board EDR is in operation. The group concluded that EDRs could improve highway safety for all vehicle classes by providing more accurate data for accident reconstructions and that EDRs have the potential to greatly improve truck, motorcoach, and school bus vehicle safety.

Responding to a Congressional directive,[89] the DOT has conducted research on the requirements for crash EDRs to facilitate the reconstruction of CMV crashes. This project was funded by the FHWA and managed by the FMCSA. The research program—the Commercial Vehicle Safety Technology Diagnostics and Performance Enhancement Program—focused on defining driver and vehicle assistance products and systems, and, in particular, advanced sensor and signal processors in trucks and tractor-trailers, with an emphasis on on-board diagnostic and improved safety-related products. The purpose of this project was to use the work products of the NHTSA EDR Working Group and additional EDR reference materials to define specific EDR requirements and functional specifications for the reconstruction of crashes involving large trucks (greater than 10,000 pounds gross vehicle weight). The program involved developing EDR requirements for the analysis of accident data from the FMCSA *Large Truck Crash Causation Study*, with the goal of developing EDR functional specifications for complete accident reconstruction and crash analyses. Requirements for EDR components, hardware, software, sensors, and databases were developed, and a cost-effectiveness analysis was completed.[90] In December 2004, the final report on the development of requirements and functional specifications for crash EDRs was published.[91] This research developed suggested requirements for EDRs to facilitate the reconstruction of CMV crashes. In addition, in 2004, the NCHRP completed a project that examined U.S. and international methods and practices for the collection, retrieval, archiving, and analysis of EDR data for roadside and vehicle safety.[92]

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[88] *Event Data Recorders: Summary of Findings by the NHTSA EDR Working Group, Volume II-Supplemental Findings for Trucks, Motorcoaches, and School Buses*, DOT HS 809 432 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, May 2002).

[89] Under Section 5117 of the Transportation Equity Act for the 21 Century of 1998, Congress required the DOT to "conduct research on the deployment of a system of advanced sensors and signal processors in trucks and tractor trailers to determine axle and wheel alignment, monitor collision alarm, check tire pressure and tire balance conditions, measure and detect load distribution in the vehicle, and adjust automatic braking systems."

[90] See FHWA IVI Program 134, *Development of Requirements and Functional Specifications for Event Data Recorders* at <http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14146.htm> (accessed June 8, 2010).

[91] J. Pierowicz, D. Fuglewicz, and G. Wilson, *Development of Requirements and Functional Specifications for Crash Event Data Recorders – Final Report*, FHWA Contract No. DTFH61-01-C-00182 (Washington, DC: Federal Highway Administration, December 2004). For additional information, see <http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14146.htm> (accessed August 24, 2010).

[92] H. Gabler and others, *Use of Event Data Recorder Technology for Highway Crash Data Analysis*, NCHRP Project 17–24, Contractor's Final Report (Washington, DC: Transportation Research Board, 2004).

Both the IEEE[93] and SAE International (SAE) have published voluntary motor vehicle EDR standards and recommended practices for industry use.[94] Industry initiatives have also included the 2004 publication, by the ATA's Technology and Maintenance Council, of RP 1214, a recommended maintenance practice that outlines the data elements, storage methodologies, and retrieval approaches for event data recording on commercial vehicles.

In August 2006, NHTSA published a final rule that standardized the information that EDRs collect; the final rule also addressed the survivability requirements for EDRs, which were based on FMVSS 208 crash testing[95] for light vehicles, including passenger cars, multipurpose passenger vehicles, and light trucks and vans with GVWRs of 8,500 pounds or less and unloaded vehicle weights of 5,500 pounds or less.[96] The final rule was amended on January 14, 2008, in response to numerous petitions for reconsideration. Based on the revised rule, the compliance dates have been changed to September 1, 2012, for most light vehicles and to September 13, 2013, for vehicles manufactured in two or more stages. The new EDR rule, however, does not mandate or require the installation of EDRs, and there is no requirement for the installation and use of EDRs on highway vehicles, including passenger vehicles, light trucks, and heavy commercial vehicles such as motorcoaches, school buses, and trucks.

Most recently, in June 2010, the SAE Truck and Bus Event Data Recorder committee published a base document, "Recommended Practice J2728—Heavy Vehicle Event Data Recorders," establishing defined specifications and functional EDR requirements for the reliable and accurate recording of the crash parameters relevant to heavy vehicles.[97]

Video Event Recorders

A video event recorder (VER) is a device designed to capture video and other parameters related to operator and vehicle performance. Current VERs are capable of recording various parameters, which may include forward-looking video, interior video, interior audio, lateral acceleration, longitudinal acceleration, and GPS position. VER systems may also be configured to record when manually activated by the driver or automatically, when preconfigured event thresholds[98] are met. VER systems are available for use in private, public, and commercial vehicles.

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[93] Formerly the Institute of Electrical and Electronics Engineers, Inc., this organization is now known exclusively by the acronym IEEE.

[94] IEEE Standard 1616-2004, *Standard for Motor Vehicle Event Data Recorders* (February 2005), and SAE Recommended Practice J1698-1, *Vehicle Event Data Recorder Interface-Output Data Format* (December 2003).

[95] The rule includes standards for 45 EDR data elements: 15 standard data elements and 30 extra data elements for advanced EDRs.

[96] See "Event Data Recorders, Final Rule," 49 CFR Part 563, NHTSA docket. no. 25666, August 28, 2006.

[97] See <http://www.fmcsa.dot.gov/documents/safety-security/MotorcoachSafetyActionPlan_finalreport-508.pdf> (accessed August 25, 2010).

[98] The manufacturer or user establishes what constitutes a "triggering event." A triggering event typically involves a threshold value for the VER's sensors; if the value is exceeded, the system saves a designated number of seconds of data (video and other types) from before and after the triggering event.

When they are installed in commercial vehicles, motor carriers sometimes use VERs as driver training tools. They also allow carriers to monitor and modify driver behavior, particularly with respect to safety. According to one VER system provider, about 120,000 vehicles are currently equipped with its VERs.

Recently, the FMCSA completed a driving behavior management system study[99] that involved installing VERs in two commercial carrier fleets and collecting data using the systems. Data from the VERs were sent to the system provider and reviewed by trained analysts. Carrier management was notified of safety-related events so that driver "interventions" could be conducted. The manager and driver would watch the event video, discuss its cause, and develop followup actions to prevent reoccurrence of the safety problem. Following the study, the two carriers indicated that they experienced a reduction in safety-related events per 10,000 miles of over 38 percent at one carrier and over 52 percent at the other. In addition, they found that severe safety-related incidents decreased by more than 59 percent and 44 percent, respectively.

[99] *Evaluating the Safety Benefits of a Low Cost Driver Behavior Management System in Commercial Vehicle Operations–Preliminary Results*, FMCSA webinar, July 22, 2009. Webinar slides available at <http://www.fmcsa.dot.gov/facts-research/media/webinar-09-07-22-slides.pdf> (accessed February 3, 2010).

Analysis

This analysis first discusses the factors and conditions that the NTSB has excluded as neither causing nor contributing to the accident. It then provides a brief overview of accident events (including the data obtained via the ECM) and discusses the following safety issues relevant to the accident: the accident truck driver's fatigue (and related factors); the need for updated and comprehensive fatigue education materials and fatigue management programs; the significance of heavy vehicle aggressivity in collisions between dissimilar vehicles; the lack of Federal requirements for heavy commercial vehicle EDRs and VERs; and the lack of Federal requirements for FCWSs.

Exclusions

The weather was clear and dry at the time of the accident. When the accident occurred about 1:19 p.m., the sun was almost directly overhead, and, therefore, it would not have been in a position to affect the driver's vision or cause glare. The NTSB concludes that the weather did not contribute to the accident. Postaccident inspection of the Volvo combination vehicle did not indicate any mechanical problems hindering the vehicle's operation and did not reveal any mechanical conditions that would have contributed to the accident. The NTSB concludes that the mechanical condition of the truck-tractor semitrailer combination unit was not a factor in this accident. The results of the toxicological analysis of the accident truck driver's blood and urine specimens were negative for alcohol and the prescription, over-the-counter, and illicit drugs for which they were tested. The NTSB concludes that the accident truck driver was not under the influence of alcohol or any of the prescription, over-the-counter, and illicit drugs for which he was tested following the accident.

Considering the challenges involved in the recovery operations, the emergency response to the accident was timely, well coordinated, and effectively managed. Appropriate resources were dispatched, and, although the distances involved and the heavy traffic did slow some responders, adequate numbers of medical and rescue personnel reached the scene quickly. The injured received medical care on scene, and they were transported to local hospitals in a timely manner. The NTSB concludes that the emergency response from the OHP, the responding fire departments, the public and private emergency medical services ambulances, the medical helicopter services, and the wrecker service was timely, and the extrication of the injured was performed as expeditiously as possible.

The highway was inspected in the area of the accident site for design and construction defects: pavement markings were visible, and no defects in the highway were found that would have caused or contributed to the crash. The guidelines in the 2004 *AASHTO Policy on Geometric Design of Highways and Streets* recommends that highway designers provide at least 820 feet of stopping sight distance in 75-mph speed zones. In this case, the stopping sight distance provided for a truck driver with a seated eye height of 96 inches from the roadway surface was 1,260 feet. Given the location of the traffic that had slowed or stopped in response to the initial accident (involving the Ford Focus), a truck driver had available sight distance and could have seen the traffic queue from the beginning of the crest vertical curve (also called a hill crest), which was approximately 5,865 feet from the traffic queue. Therefore, the NTSB concludes that no highway design or construction defects existed in the area of the accident site, and the available sight distance for the accident truck driver to observe the traffic queue and stop his vehicle exceeded the stopping sight distance recommended by AASHTO.

The NTSB found that the truck driver had made and received cellular telephone calls while on duty on the day of the accident, including engaging in a 22-minute-long call that ended about 10 minutes prior to the crash. AWG policy, as reflected in its employee handbook, is that AWG employees may not use their cellular telephones in any fashion while performing their duties. Therefore, the NTSB concludes that the cellular telephone activity in which the truck driver engaged while on duty failed to comply with AWG written policy.

Electronic Control Module

Although the accident truck-tractor's ECM was designed with an EDR function, it lacked the degree of parameters and precision of dedicated EDR devices intended to capture and provide event data required in the reconstruction of complex collision events. It was capable of recording various operating parameters in connection with critical diagnostic events, as well as precrash data in connection with sudden deceleration events. The ECM provided the NTSB with some valuable data associated with the operation of the Volvo truck-tractor, including that the vehicle brakes were not engaged during the crash sequence, that the cruise control was engaged, and that the ECM-recorded speed of the vehicle was 70 mph at time of impact. Investigators subsequently adjusted the 70-mph recorded speed to approximately 68.70 mph, based on vehicle condition data and other factors. The NTSB concludes that, based on the available ECM data and analysis, the truck driver failed to apply the brakes at any time prior to, during, or after striking the slowed and stopped vehicles in the traffic queue and was operating the accident truck with the cruise control engaged at a speed of about 69 mph.

Accident Discussion

Postaccident interviews with several drivers involved in the accident and accident witnesses, as well as the physical evidence at the scene and the vehicle damage, indicate that the passenger vehicles struck by the Volvo truck-tractor semitrailer were traveling at lower speeds than the Volvo. The vehicles were slowing in response to a queue of traffic ahead that was moving intermittently and slowing from the posted speed limit of 75 mph due to another accident farther ahead that was blocking the left lane of the interstate. The accident Volvo struck the slower moving vehicles while traveling about 69 mph, based on the Volvo's interpreted ECM data. Physical evidence on the roadway showed that the Volvo traveled about 270 feet from first impact to final rest, causing a chain reaction of vehicle impacts that included six passenger vehicles and one livestock trailer.

Four of the six passenger vehicles sustained catastrophic damage from being struck by the Volvo combination unit. The first vehicle struck by the Volvo was the Land Rover; the truck-tractor's front bumper was higher than the Land Rover's, so the Volvo overrode the smaller vehicle and intruded into its occupant compartment, crushing it inward several feet before pushing the Land Rover off the right side of the roadway. The second vehicle struck was the Hyundai; the Land Rover hit it first in the rear right corner, which rotated the Hyundai slightly counterclockwise. Then, the Volvo truck-tractor hit the Hyundai and pushed it forward into the Kia sedan. The Volvo continued forward and (due to the high impact speed, its taller bumper, and its heavier structure) drove over the Hyundai, which was caught under the truck-tractor's dual wheels when it came to rest.

The third vehicle struck was the Kia sedan; it was hit first by the Hyundai and then by the Volvo truck-tractor. The Volvo then drove over the Kia. The Kia ended up directly under the truck-tractor's second axle. The fourth vehicle struck from the rear by the Volvo was the Windstar minivan. The Volvo overrode it and crushed the Windstar occupant compartment structure forward, almost to the front seatbacks. The last two passenger vehicles, the F350 pickup truck (towing a livestock trailer) and the Chevrolet Tahoe, sustained moderate damage but no intrusion into their occupant compartments. The Volvo did not strike these vehicles directly; however, the Windstar was pushed forward into the trailer being pulled by the F350, causing the pickup truck and the trailer to be pushed forward into the Tahoe.

Driver

Medical Factors

The Miami accident truck driver was witnessed executing a lane change before striking the line of stopped vehicles. During medical treatment after the accident, the driver said he did not clearly recall the events of the accident, and, given the nature of his head injuries, it is likely that his memory was disrupted and inaccurate.[100] It cannot be conclusively established that the driver was awake/conscious at the exact time of the accident, but he was certainly awake/conscious when he shifted lanes prior to it, when the queue of slowing and stopped vehicles in both lanes would have been clearly visible to him.

The driver's failure to initiate any sort of action to avoid the accident suggests a complete lack of awareness of, and/or inability to respond to, the line of vehicles in front of him. No compelling medical explanation for his behavior was identified through comprehensive postaccident medical testing. Although there are conditions—including a complex partial seizure, a transient ischemic attack (mini-stroke), a psychological disorder, or a sudden sustained abnormal heart rhythm—that might explain a sudden loss of awareness or inability to act, no clinical evidence was found that any of those conditions had occurred. Further, there is no evidence that the driver experienced any such event in the months/years preceding or in the

[100] After the accident, the driver was admitted to a local hospital for treatment of a nondisplaced fracture of the jaw, a brain contusion, and facial swelling and lacerations sustained in the accident.

weeks following the accident, and the diagnoses of such events are not consistent with the driver's witnessed behavior immediately before and after the accident. Therefore, the NTSB concludes that based on the medical evidence and witness accounts concerning the accident truck driver's behavior and condition, it is unlikely that he experienced a medical event that might have caused or contributed to the accident.

Fatigue

The NTSB considered whether the driver might have been impaired by the effects of fatigue at the time of the accident. "Fatigue" is a term that is often used interchangeably with sleepiness or drowsiness and, for the purposes of this report, refers to the decreased alertness that is associated with sleep deprivation, circadian disruption,[101] and continuous time awake.

Fatigue has been found to lead to performance impairments such as slowed reaction time, reduced vigilance, and impaired cognitive processing.[102] It also has been found to affect the variability of gaze location, suggesting perceptual narrowing.[103] For example, after changing lanes, a fatigued driver may keep looking into his vehicle's mirrors too long, instead of quickly refocusing on the road ahead. In addition, fatigue has been found to result in gaze fixations closer to the driver's own vehicle, a behavior that would decrease the time available to perceive and react to a dangerous situation ahead. Fatigue could lead to onset of a microsleep, which is an event lasting a few seconds in which a person loses consciousness and directly enters a sleeping period. People often have no memory of these events occurring; and, of course, a driver would have limited control over a vehicle while in a microsleep.[104]

The accident truck driver would not speak to NTSB investigators postaccident. Consequently, information about the driver is based on the Mobius OBC record-of-duty logs, his medical records, his cellular telephone records, witness statements regarding his behavior prior to and following the accident, data from the Volvo's ECM, and the physical evidence at the accident scene.

Circadian Disruption and Acute Sleep Loss. The driver was engaged in nighttime shift work. Research suggests that the quality of sleep of those involved in shift work is generally inferior to those who work a normal schedule.[105] The driver generally went on duty between 2:00 and 3:00 a.m., a time when most individuals are physiologically and psychologically least

[101] Also known as "circadian dysrhythmia," this is a disruption of circadian rhythms due to a shift in the daily schedule that may be caused by factors such as rotating shift work or multi-time-zone travel.

[102] D. Dinges and N. Kribbs, "Performing While Sleepy: Effects of Experimentally Induced Sleepiness," in T. Monk, ed., *Sleep, Sleepiness, and Performance* (Chichester, UK: John Wiley & Sons, 1991), pp. 98–128.

[103] (a) N. Kaluger and G. Smith, *Driver Eye-Movement Patterns Under Conditions of Prolonged Driving and Sleep Deprivation* (Washington DC: Highway Research Record, 1970), pp. 92–106. (b) P. Green, "Where Do Drivers Look While Driving (And For How Long)?," in *Human Factors in Traffic Safety*, R. Dewar and P. Olson, eds. (Tucson, Arizona: Lawyers and Judges Publishing, 2002), p. 97.

[104] L. Boyle and others, "Driver Performance in the Moments Surrounding a Microsleep," *Transportation Research, Part F, Traffic Psychology and Behavior*, vol. 11, no. 2 (March 2008), pp. 126-136.

[105] G. Richardson and H. Malin, "Circadian Rhythm Sleep Disorders: Pathophysiology and Treatment," *Journal of Clinical Neurophysiology*, vol. 13, no. 1 (January 1996), pp. 17–31.

alert. On some occasions, the driver would begin work slightly earlier than 2:00 a.m. or as late as 5:00 a.m.

According to his postaccident sleep study records, the driver stated that when he was scheduled to work, he generally attempted to go to sleep about 8:00 p.m. and woke up between 12:30 and 1:00 a.m. He further stated that since he had stopped working, he went to bed around 10:00 p.m. and awoke between 6:00 and 7:00 a.m. This suggests that the driver normally required 8 to 9 hours of sleep per night, which is consistent with normal human sleep requirements, but he received at most 4.5 to 5 hours of sleep on the nights/days that he worked.

The driver had returned to work 4 days before the accident, on June 22, after an extended period of absence; but on that occasion, he worked only for a relatively short 5.5-hour shift that began at 5:00 a.m. Had the driver gone to sleep at 8:00 p.m., as he stated he normally attempted to do prior to a work shift, it is possible he would have obtained an adequate amount of sleep and been reasonably alert during this shorter shift.

The day of the accident, June 26, was the first time in 3 weeks that the driver had worked a long shift, which required an earlier shift start time of 3:00 a.m. Had the driver gone to sleep at 8:00 p.m. and awoken at 1:00 a.m., he would have had the opportunity to obtain a maximum of 5 hours of sleep, which was 3–4 hours less than his typical sleep requirement. Such acute sleep deprivation has been found to increase the risk of an injury crash, with a 2-hour sleep loss resulting in noticeable decrements in divided attention and vigilance.[106] Additionally, drivers who reported getting 5 hours sleep or less in the previous 24 hours had an almost threefold increase in risk for an injury crash.[107]

In the 3 weeks prior to the accident, the Miami accident driver had worked only once and had probably reverted to a typical diurnal sleep–wake schedule similar to the one he described as having since the accident (that is, going to bed about 10:00 p.m. and rising about 7:00 a.m.). Consequently, at the time of the accident, it is very likely that the driver's circadian rhythms mirrored those of an individual keeping a typical daytime schedule. Therefore, on the night before the accident,[108] the driver would have been trying to fall asleep 2 hours earlier than usual. This significant phase advance is beyond the range of entrainment for the circadian clock and would have resulted in significant sleep latency and shortened total sleep time.[109] Given the self-reported circadian phase advance of the driver's bedtime, it is possible that he may have obtained as little as 3 hours of quality sleep prior to the accident, resulting in a total of 5 hours of

[106] (a) T. Roehrs and others, "Ethanol and Sleep Loss: A 'Dose' Comparison of Impairing Effects," *Sleep*, vol. 26, no. 8 (December 15, 2003), pp. 981-985. (b) M. Carskadon and T. Roth, "Sleep Restriction," in *Sleep, Sleepiness, and Performance*, pp. 155-167.

[107] J. Connor and others, "Driver Sleepiness and Risk of Serious Injury to Car Occupants: Population Based on Case Control Study," *British Medical Journal*, vol. 324, no. 7346 (May 11, 2002), p. 1125.

[108] This was his first day driving after 3 days off and his second day driving after having been off duty for about 3 weeks.

[109] (a) S. Folkard and J. Barton, "Does the 'Forbidden Zone' for Sleep Onset Influence Morning Shift Sleep Duration?," *Ergonomics*, vol. 36, no. 1-3 (January 1993), pp. 85–91. (b) T. Monk and others, "Inducing Jet-Lag in Older People: Directional Asymmetry," *Journal of Sleep Research*, vol. 9 (2000), pp. 101-116. (c) R. Manfredini and others, "Circadian Rhythms, Athletic Performance, and Jet Lag," *British Journal of Sports Medicine,* vol. 32 (1998), pp. 101–106.

acute sleep loss prior to the crash. Furthermore, the driver would have begun driving during the window of a circadian low, making him more prone to fatigue and decrements in attention and performance.[110] Finally, the accident occurred in the early afternoon, about the time when individuals on a standard daytime schedule would begin to experience a mid-afternoon dip in performance. It is highly probable that the combined effects of acute sleep loss, his shift work schedule, and a mid-afternoon decline in performance resulted in the accident driver being fatigued at the time of the accident.

Obstructive Sleep Apnea. The driver had several risk factors associated with OSA, including his age, his gender, his BMI of 34.4, and his history of hypertension.[111] The driver had been hospitalized for 2 days approximately 3 weeks prior to the accident concerning complaints of his having "chest pressure, weakness and shortness of breath" for several months. Cardiovascular evaluation failed to identify a cause for his symptoms, but his hospital discharge summary stated that the driver "describes excessive daytime tiredness and loud snoring at night, raising the possibility of OSA." The driver did not undergo an evaluation for OSA at that time. After the June 26, 2009, accident, the attending physician noted in his treatment recommendation that "The patient probably has an underlying sleep apnea and he is counseled yet again with his family members that he needs an outpatient sleep study." On August 2 and 18, 2009, the driver took part in sleep studies conducted by an accredited sleep disorders clinic, and the results indicated that he had mild OSA.

OSA is a common diagnosis among commercial drivers. The majority of OSA patients have symptoms related to poor quality sleep, such as excessive daytime sleepiness and tiredness, lack of concentration, and memory impairment.[112] A 2002 review of the epidemiology of OSA estimated that roughly 7 percent of adults have at least moderate OSA.[113] An FMCSA-commissioned study on the prevalence of OSA in commercial drivers found that 17.6 percent of drivers studied had mild OSA, 5.8 percent had moderate OSA, and 4.7 percent had severe OSA.[114] Individuals with the disorder may have extreme daytime sleepiness. They often fall asleep within minutes in a quiet or monotonous environment, which puts them at risk for falling asleep while driving. OSA is associated with significant cognitive and psychomotor deficits; such deficits[115] are of particular concern for commercial drivers operating in highway conditions, where immediate and appropriate responses to external stimuli are often critical to safety. A recent meta-analysis on OSA and motor vehicle crash risk found that drivers with OSA

[110] M. Kryger, T. Roth, and W. Dement, *Principles and Practice in Sleep Medicine*, 4th edition (Philadelphia, Pennsylvania: Elsevier-Saunders, 2005), pp. 680–690.

[111] *Principles and Practice in Sleep Medicine*, pp. 33, 1045, and 1195.

[112] M. D'Ambrosio and others, "Quality of Life in Patients with Obstructive Sleep Apnea: Effect of Nasal Continuous Positive Airway Pressure—A Prospective Study," *Chest*, vol. 115, no. 1 (1999), pp. 123-129. Also see <http://chestjournal.chestpubs.org/content/115/1/123.full.html> (accessed September 24, 2010).

[113] T. Young, P. Peppard, and D. Gottlieb, "Epidemiology of Obstructive Sleep Apnea: A Population Health Perspective," *American Journal of Respiratory and Critical Care Medicine*, vol. 165, no. 9 (2002), pp. 1217–39.

[114] *A Study of Prevalence of Sleep Apnea Among Commercial Truck Drivers,* FMCSA-RT-02-080 (Washington, DC: Federal Motor Carrier Safety Administration, July 2002).

[115] Some of these deficits are at least partially reversible with appropriate treatment.

have an increased crash risk compared to the general driving population.[116] The NTSB has investigated several accidents in which OSA was determined to be causal. As a result, the NTSB has issued recommendations[117] focused on increasing awareness of the disease among drivers, employers, and physicians, as well as on instituting a program to identify drivers at high risk for the disorder and to treat those diagnosed. In October 2009, the NTSB issued the following safety recommendations to the FMCSA:

> Implement a program to identify commercial drivers at high risk for obstructive sleep apnea and require that those drivers provide evidence through the medical certification process of having been appropriately evaluated and, if treatment is needed, effectively treated for that disorder before being granted unrestricted medical certification. (H-09-15)
>
> Develop and disseminate guidance for commercial drivers, employers, and physicians regarding the identification and treatment of individuals at high risk of obstructive sleep apnea (OSA), emphasizing that drivers who have OSA that is effectively treated are routinely approved for continued medical certification. (H-09-16)

The FMCSA responded to both recommendations in a February 1, 2010, letter, which indicated that the agency agreed with the recommendations. With respect to Safety Recommendation H-09-15, the FMCSA indicated that it is considering rulemaking in response to its Medical Review Board recommendations regarding pulmonary/respiratory requirements (including those addressing sleep disorders) for driver medical qualifications, and that, pending completion of any rulemaking, it had undertaken new initiatives to strengthen the certification process for drivers at risk for OSA and other sleep disorders. In response to Safety Recommendation H-09-16, the FMCSA indicated that the agency is developing medical examiner, employer, and driver guidance on sleep disorders, including OSA. The letter also stated that the FMCSA would sponsor a 2010 National Sleep Apnea and Trucking Conference in Baltimore, Maryland,[118] and would be taking and planning additional initiatives to satisfy the recommendation. Based on these responses, on July 20, 2010, the NTSB classified Safety Recommendations H-09-15 and -16 "Open—Acceptable Response."

The NTSB recognizes that no reasonable screening protocol can identify every case of OSA, particularly in cases of mild disease. For the truck-tractor driver in this accident, the application of at least one set of screening guidelines probably would not have resulted in his being evaluated for sleep apnea prior to the accident. Under those guidelines, published by a joint task force on OSA screening, composed of representatives of the American College of Chest Physicians, the American College of Occupational and Environmental Medicine, and the National Sleep Foundation, the accident driver most likely would not have met the criteria for screening because his BMI was under 35 (34.4 based on height and weight reported at his most recent examination), he did not report sleepiness or snoring on his examination reports, his blood pressure was controlled on one medication as of his last examination, and his neck circumference

[116] S. Tregear and others, "Obstructive Sleep Apnea and Risk of Motor Vehicle Crash: Systematic Review and Meta-analysis," *Journal of Sleep Medicine*, vol. 5, no. 6 (August 2009), pp. 573-581.

[117] To view the recommendation letter to the FMCSA on this issue, which refers to several accidents that involved OSA, see <http://www.ntsb.gov/Recs/letters/2009/H09_15_16.pdf> (accessed June 8, 2010).

[118] The conference was held May 11–12, 2010.

was less than 17 inches. The joint task force also identified age as a risk factor for OSA. Although age is associated with changes in sleep patterns and an increased risk of OSA,[119] there were no indications that the driver's sleep schedule or mild OSA were directly related to his age. Regardless of whether the screening guidelines would have identified this driver as at-risk, a program for the identification of drivers with OSA remains an important component of effective fatigue management. Therefore, the Board encourages the FMCSA to continue its work in this important area and looks forward to full implementation of Safety Recommendations H-09-15 and -16.

In summary with respect to the Volvo truck driver, his normal sleep range was between 8 and 9 hours, but he most likely obtained no more than 5 hours sleep the night before the accident. The driver's circadian rhythms, which were fully entrained to a daytime schedule after almost 3 weeks off work, were disrupted by the advanced phase shift of his sleep time and by the early morning start time of his shift work. Moreover, the accident occurred about the time when individuals on a standard daytime schedule would begin experiencing a mid-afternoon dip in performance. In addition, this was the first time in 3 weeks that the driver had worked an extended shift schedule, and he would have been continuously awake for about 12 hours and have been driving for about 10 hours at the time of the accident. Any sleep that the driver did obtain would have been negatively affected by his mild OSA. Therefore, the NTSB concludes that the accident truck driver was impaired by fatigue at the time of the crash as a result of acute sleep loss, circadian disruption associated with his shift work schedule, and mild OSA.

According to a commercial driver who witnessed the accident, the accident driver's truck passed his vehicle in the left lane and then shifted into the right lane before colliding with the queue. The available sight distance from the hill crest to the impact area was 4,695 feet. Given a speed of about 69 mph, the accident driver would have had more than 45 seconds to perceive and react to the traffic queue. For an alert driver of a truck-tractor semitrailer with adequate brakes, this would have been more than enough time to stop at highway speeds.

The accident driver not only did not stop, he did not even attempt to stop or to take evasive action, such as a swerve to the right shoulder. While in a reduced state of alertness, the driver may have been able to acknowledge and react to common, slow-developing highway occurrences, such as approaching and overtaking a truck or checking mirrors and changing lanes. For example, the left-to-right lane change the driver executed as he crested the hill could be considered a routine response to a commonly encountered highway situation. However, because a stopped traffic queue is a relatively uncommon occurrence on a rural interstate such as I-44, in his highly fatigued state, the accident driver might not have had time or capability to see, process, and react to the queue until it was too late. It is also possible that the driver experienced a lapse in attention or the onset of a microsleep, both of which would have precluded any reaction to the impending traffic queue. Lapses in attention and performance are common characteristics of fatigue-related accidents, and the Miami driver's behavior leading up to the

[119] (a) T. Young, J. Skatrud, and P. Peppard, "Risk Factors for Obstructive Sleep Apnea in Adults," *Journal of the American Medical Association*, vol. 291 (2004), pp. 2013-2016. (b) D. Bliwise, "Normal Aging," in *Principles and Practice in Sleep Medicine*, pp. 24-38.

accident is consistent with the fatigue literature.[120] Therefore, the NTSB concludes that the truck driver's impairment from fatigue led to his failure to react to the slowing and stopped traffic ahead by applying brakes or performing any evasive maneuver to avoid colliding with the traffic queue.

Fatigue Education and Information. The NTSB has long been concerned about how fatigue affects all transportation operators, including commercial truck and bus drivers. In 1990, the NTSB completed a study of 182 heavy truck accidents that were fatal to the truck driver.[121] The NTSB's primary purpose in investigating fatal-to-the-truck-driver accidents was to assess the role of alcohol and other drugs in these accidents. The study found, however, that the most frequently cited probable cause in such accidents was fatigue. In a subsequent safety study that focused on fatigue's role in heavy truck accidents,[122] the NTSB recommended that the FHWA,[123] in cooperation with the ATA, the Professional Truck Driver Institute, the Commercial Vehicle Safety Alliance (CVSA), and the National Private Truck Council, take the following action:

> Develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truck drivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (H-95-5)

The FHWA Office of Motor Carriers distributed pamphlets; worked with the Owner-Operator Independent Drivers Association, the CVSA, and the National Private Truck Council on this issue; and sponsored the DOT 1995 Truck and Bus Summit. It also funded the ATA to adapt the sleep education and training module developed by the National Aeronautics and Space Administration to the motor carrier industry and to identify, evaluate, and select recommended management practices for determining which drivers are at higher risk of accidents and safety violations and for developing means of appropriately modifying driver behavior. The development and distribution of brochures, manuals, and videotapes, such as "The Alert Driver: A Trucker's Guide to Sleep, Fatigue, and Rest in Our 24-Hour Society," "Awake at the Wheel," "Fatigue and the Truck Driver," and "Dealing with Truck Driver Fatigue," publicized the importance of the issue of fatigue. The FHWA stated that it would continue its educational activities and that the strategic plan for its Office of Motor Carriers (predecessor entity to the FMCSA) would include educational and informational approaches. Safety

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[120] (a) D. Dinges and N. Kribbs, "Performing While Sleepy: Effects of Experimentally Induced Sleepiness," in *Sleep, Sleepiness, and Performance*, pp. 155-167. (b) S. Banks and D. Dinges, "Behavioral and Physiological Consequences of Sleep Restriction," *Journal of Clinical Sleep Medicine*, vol. 3, no. 5 (June 2007), pp. 519-528. (c) J. Horne and L. Reyner, "Sleep-Related Vehicle Accidents," *British Medical Journal,* vol. 310, no. 565 (March 1995).

[121] *Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-To-The-Driver Heavy Truck Crashes (Volume 1)*, Safety Study NTSB/SS-90/01 (Washington, DC: National Transportation Safety Board, 1990).

[122] *Factors That Affect Fatigue in Heavy Truck Accidents, Volume 1: Analysis*, Safety Study NTSB/SS-95/01 (Washington, DC: National Transportation Safety Board, 1995).

[123] Within the DOT, the FMCSA subsequently became responsible for these areas of concern.

Recommendation H-95-5 was classified "Closed—Acceptable Action" on July 7, 1998, due to the agency's work with various organizations to educate drivers about the dangers of drowsy driving.

When NTSB investigators reviewed the training material AWG provided its drivers, they found the VHS videotape "The Alert Driver: A Trucker's Guide to Sleep, Fatigue, and Rest in Our 24-Hour Society," which was released in 1996 by the ATA, in partnership with the FHWA Office of Motor Carriers (since succeeded by the FMCSA). Although the video provides valuable guidelines for truck drivers regarding the importance of sleep, the cognitive effects of sleepiness, and the best strategies to reduce fatigue related to shift work, some of the information provided is outdated, and the video does not include vital fatigue-related facts and guidance. For example, the video references obsolete HOS regulations; the FMCSA significantly revised these regulations in April 2003, limiting driving to 11 hours within a 14-hour, nonextendable period after coming on duty following 10 consecutive hours off duty (known as the 11-hour rule).[124] The video also does not mention the risk factors for OSA, which is a significant omission, given the prevalence of these factors among commercial drivers.[125] Further, the driver fatigue video does not mention the importance of maintaining one's health and diet to reduce fatigue.[126] Research has revealed how a health and wellness regimen can reduce the risk factors that may lead to fatigue and drowsiness.[127] A booklet that accompanies the video includes some information on health maintenance and OSA risk factors; however, because the video is the primary mode of information dissemination, the relegation of this information to a supplementary booklet makes it less likely that it will be seen and heeded by truck drivers.

In addition, the 1996 video provides questionable strategies for truck drivers to follow in combating sleepiness, such as chewing gum, eating sunflower seeds, turning on the radio, and rolling down the window.[128] On its website, the FMCSA has discouraged the use of such "alertness tricks," stating that they are not "real cures for drowsiness and may give you a false sense of security."[129]

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[124] Although the rules concerning weekly limits for on-duty time remained unchanged, drivers were allowed to restart the weekly limit calculation after they took 34 consecutive hours off duty (known as the 34-hour restart provision). The rule also extended the requisite off-duty time from 8 to 10 hours, providing drivers more time for restorative rest.

[125] (a) R. Stoohs and others, "Sleep and Sleep-Disordered Breathing in Commercial Long-Haul Truck Drivers," *Chest*, vol. 107, no. 5 (1995), pp. 1275–1282. (b) H. Häkkänen and H. Summal, "Sleepiness at Work Among Commercial Truck Drivers," *Sleep*, vol. 23, no. 1 (2000), pp. 49–57.

[126] (a) J. Brock and others, *Commercial Truck and Bus Safety Synthesis 7: Motorcoach Industry Hours of Service and Fatigue Management Techniques* (Washington, DC: Transportation Research Board, 2005). (b) *Fatigue Survey of BC Truck Drivers* (WorkSafeBC, December 2005), <http://www2.worksafebc.com/pdfs/forestry/truck_driver_fatigue_survey_final.pdf> (accessed June 8, 2010). (c) D. Wiegand, R. Hanowski, and S. McDonald, *Commercial Motor Vehicle Health and Fatigue Study Final Report*, 09-UF-002 (Blacksburg, Virginia: National Surface Transportation Safety Center for Excellence, February 11, 2009).

[127] (a) R. Stoohs and others. (b) H. Häkkänen and H. Summal. (c) *Fatigue Survey of BC Truck Drivers*.

[128] A witness stated that the Volvo cab's driver-side window was rolled down at the accident scene, despite the temperature being above 100 °F. This was confirmed in postaccident scene photos. However, it is not known whether the window was opened before or immediately following the accident.

[129] See <http://www.fmcsa.dot.gov/about/outreach/education/driverTips/Driver-fatigue.htm> (accessed November 3, 2009).

The NTSB concludes that the provision of new and updated information on sleep, fatigue, and alertness by the FMCSA, based on contemporary scientific research, is essential to ensuring that commercial drivers have the necessary guidance to enable them to be alert and well rested when operating their vehicles. Updating the information being provided to truck drivers on fatigue and fatigue countermeasures, HOS, and OSA may help to reduce accidents caused by fatigue; therefore, the NTSB recommends that the FMCSA create educational materials that provide current information on fatigue and fatigue countermeasures and make the materials available in different formats, including updating and redistributing its truck-driver-focused driver fatigue video. Further, the FMCSA should make the video available electronically for quicker dissemination, and it should implement a plan to regularly update the educational materials and the video with the latest scientific information and to regularly redistribute them.

Fatigue Management Programs. Although employee education concerning fatigue is extremely valuable, the provision of information alone is insufficient to constitute an adequate fatigue management program, which should involve all aspects of a carrier's operation. A fatigue management program is a system[130] designed to take a comprehensive, tailored approach to the issue of fatigue within an industry or a workplace and to address the problem of fatigue in an operational environment. Commonly, a fatigue management program would incorporate individual program-focused efforts to help manage fatigue (for example, policies and practices addressing scheduling;[131] attendance; employee education, medical screening, and treatment; personal responsibility during nonwork periods; task/workload issues; rest environments; and commuting and/or napping) as well as an overall organizational strategy for implementing, supervising, and evaluating the plan. Many motor carriers have developed and put into action their own fatigue management programs, although the extent and nature of the plans vary widely.

AWG operates around the clock and its drivers work on shift schedules, yet the NTSB found no evidence that the carrier had taken any companywide action to minimize the occurrence of fatigued driving. Apart from including the outdated "Alert Driver" video in its training library, AWG did not have any program in place to prepare and educate its dispatchers, managers, and drivers to deal with the fatigue-related consequences of its shift work operations. The NTSB concludes that AWG did not have a meaningful fatigue management program in place at the time of the accident.

The FMCSA is currently collaborating with Transport Canada and others on the development of the NAFMP, which will provide companywide guidelines for the management of fatigue in a motor carrier operating environment. The NAFMP guidelines are envisioned to promote the following elements: (1) corporate change processes, including the involvement and support of management, (2) modifications to scheduling policies and practices, (3) companywide fatigue management training, (4) sleep disorder screening and treatment for drivers, and (5) fatigue-monitoring technologies and alertness strategies. The NAFMP fatigue management

[130] Fatigue management systems can also be referred to as fatigue management plans, fatigue risk management programs, fatigue management schemes, fatigue countermeasures programs, and alertness management programs. For the purposes of this report, the term "fatigue management program" will be used when referring generically to such systems.

[131] Scheduling policies and practices could include written policies and/or the use of fatigue-modeling software tools to assist in roster development.

guidelines are anticipated to be available within the next 2 years; they will be applicable to all motor carrier operations, industrywide, regardless of size.

Because of the complex nature of the factors that contribute to fatigue, not only has the NTSB issued safety recommendations regarding fatigue in all modes, but it has also supported industry initiatives led by the DOT to develop practical fatigue management tools for the transportation industry.[132] For example, in the late 1990s, the DOT's Human Factors Coordinating Committee, a group consisting of representatives from the FAA and other transportation modal administrations, sponsored an Operator Fatigue Management (OFM) Program.[133] The program resulted in several products, including a practical guide addressing fatigue management and countermeasure usage[134] and work schedule representation and analysis software to aid managers and schedulers in evaluating and designing work schedules and procedures for validating the output of fatigue-modeling tools. In response to Safety Recommendation A-06-11, which the NTSB issued to the FAA in its report on the Kirksville, Missouri, aircraft accident,[135] on April 28, 2006, the FAA issued *Safety Alert for Operators 06004*, which informed aviation operators of the fatigue-related information in the DOT OFM program. According to DOT and industry personnel, the Federal Railroad Administration has tested and applied some of the OFM program tools in the railroad industry.[136]

In addition, the Rail Safety Improvement Act of 2008[137] states that the Secretary of Transportation, by regulation, shall require each railroad carrier that is a Class I railroad,[138] a railroad carrier that has inadequate safety performance (as determined by the Secretary), or a railroad carrier that provides intercity rail passenger or commuter rail passenger transportation to develop and update, at least once every 2 years, a fatigue management plan designed to reduce the fatigue experienced by safety-related railroad employees, as well as the likelihood of accidents, incidents, injuries, and fatalities caused by fatigue. Further, the Airline Safety and FAA Extension Act of 2010[139] will require all Part 121 air carriers to submit to the FAA a fatigue risk management plan for its pilots so that the FAA can review and accept it. The plan

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[132] (a) *Collision With Trees on Final Approach, Federal Express Flight 1478, Boeing 727-232, N497FE, Tallahassee, Florida, July 26, 2002*, Aircraft Accident Report NTSB/AAR-04/02 (Washington, DC: National Transportation Safety Board, 2004). (b) *Collision with Trees and Crash Short of Runway, Corporate Airlines Flight 5966, British Aerospace BAE-J3201*, N875JX*, Kirksville, Missouri, October 19, 2004*, Aircraft Accident Report NTSB/AAR-06/01 (Washington, DC: National Transportation Safety Board, 2006).

[133] This program was established as part of the "ONEDOT" program to coordinate resources among DOT agencies. One of the goals of the effort was to reduce the number of accidents and injuries related to operator fatigue.

[134] *Commercial Transportation Operator Fatigue Management Reference* (Washington, DC: U.S. Department of Transportation, Research and Special Programs Administration, 2003).

[135] NTSB/AAR-06/01.

[136] *Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, Summary Report*, DOT-06/21 (Washington, DC: U.S. Department of Transportation, Federal Railroad Administration, 2006).

[137] For additional information, see <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h2095enr.txt.pdf> (accessed August 12, 2010).

[138] A Class I railroad is one that has annual carrier operating revenues that meet the threshold amount for Class I carriers as determined by the Surface Transportation Board under 49 CFR 1201.1-1.

[139] For additional information, see <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h5900rds.txt.pdf> (accessed August 19, 2010).

must include annual fatigue management training for pilots, a work/rest policy to help manage pilot fatigue, and a methodology to assess the effectiveness of the program. Air carriers will also be required to update and resubmit their plans to the FAA every 2 years.

The FMCSA has not yet applied such guidance or requirements concerning fatigue management programs in the motor carrier industry. However, until the FMCSA issues guidance to operators on the best practices to apply in developing a fatigue management program, other resources are available to help motor carriers create comprehensive companywide policies and processes for reducing fatigue-related accidents. For instance, organizations such as the National Institute for Occupational Safety and Health and NHTSA provide updated information and pamphlets related to shift work that could be used as a starting point for developing a fatigue management program.[140] In addition, the DOT makes available general fatigue management resources and tools through the efforts of its Human Factors Coordinating Committee.[141]

The goal of a fatigue management program is to mitigate human fatigue, thereby reducing the probability of human-error-caused incidents and accidents. Pilot studies conducted for the NAFMP have shown positive results with respect to driver sleep lengths and reduction in critical driving events.[142] Other modes of transportation—in particular, aviation and rail—have moved toward mandating fatigue management programs for their modal carriers. The NTSB concludes that the use of fatigue management programs by motor carriers has the potential to reduce accidents caused by fatigued commercial drivers. Given that its lack of an effective fatigue management program contributed to an environment that did not sufficiently emphasize the importance of fatigue awareness and countermeasures among its drivers, the NTSB recommends that AWG create and implement a comprehensive fatigue management program using existing sources of information, and develop a systematic process to update the program as more guidance becomes available.

To be most effective, a fatigue management program should be comprehensive and authoritative. Within the next 2 years, the NAFMP is expected to provide fatigue management program guidelines specifically designed for use in the motor carrier environment. Implementation of these guidelines by every motor carrier would be a major step toward addressing the problem of fatigue among commercial drivers on the nation's highways. But if the NAFMP guidelines remain voluntary—and are used by some carriers but ignored by others—this important safety tool might have only a limited effect in reducing fatigue-related highway accidents. Consequently, the NTSB recommends that the FMCSA require all motor carriers to adopt a fatigue management program based on the NAFMP guidelines for the management of fatigue in a motor carrier operating environment.

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[140] For additional information, see <http://www.cdc.gov/niosh/topics/workschedules/> and <http://www.nhtsa.gov/people/injury/drowsy_driving1/human/drows_driving/resource/resource.html> (accessed August 24, 2010).

[141] See <http://hfcc.dot.gov/ofm/index.html> (accessed August 19, 2010).

[142] (a) A. Moscovitch and others, *Development of a North American Fatigue Management Program for Commercial Motor Carriers: Phase II (Pilot Study)*, TP 14828E (Ottawa, Ontario: Transport Canada, January 2006). (b) A. Smiley and others, *Effects of a Fatigue Management Program on Fatigue in the Commercial Motor Carrier Industry: Summary Report*, TP 14921E (Ottawa, Ontario: Transport Canada, September 2009).

The NTSB referenced the NAFMP in its report on an early morning collision between a truck-tractor semitrailer and a motorcoach near Osseo, Wisconsin.[143] Although the NTSB has supported the NAFMP effort to create fatigue management guidelines, in the Osseo report, it also expressed concern that motor carriers have been evaluating their own fatigue management programs without expert oversight. The NTSB considered that the FMCSA, as the Federal agency responsible for motor carrier safety, must also be involved in the evaluation of the fatigue management programs used by carriers to determine whether they successfully mitigate fatigue. The NTSB concluded that for fatigue management programs to be successful, FMCSA oversight is needed; therefore, the NTSB made the following recommendation to the FMCSA:

> 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)

Based on the FMCSA's continuing work with the NAFMP, Safety Recommendation H-08-14 is currently classified "Open—Acceptable Response." The NTSB considers that the circumstances of the Miami accident again demonstrate the serious nature of fatigue-related accidents and the need for effective fatigue management programs and oversight of such programs; therefore, the Board reiterates Safety Recommendation H-08-14, and it remains classified "Open—Acceptable Response."

Also in the Osseo accident report, the NTSB concluded that 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. Consequently, the NTSB issued another recommendation regarding fatigue to the FMCSA, as follows:

> Develop and implement a plan to deploy technologies in commercial vehicles to reduce the occurrence of fatigue-related accidents. (H-08-13)

On May 11, 2009, the FMCSA responded to this recommendation and indicated that the development of an advanced Drowsy Driver Warning System was underway and would move into principal research and prototype development in 2009. The FMCSA projected that this phase would last 2 years, after which a commercialization decision would be made. The FMCSA has acknowledged that driver drowsiness poses a major threat to highway safety, given the 24-hour operations, high annual mileages, challenging environmental conditions, and demanding work schedules faced by commercial drivers today.[144] However, in its response to the NTSB, the FMCSA specifically stated that it was unaware of any available technology that could be used by commercial drivers for both day and night driving. The NTSB responded that although the FMCSA was correct that no products were currently available commercially that could be used

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[143] *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: National Transportation Safety Board, 2008).

[144] *An Evaluation of Emerging Driver Fatigue Detection Measures and Technologies*, Tech Brief FMCSA-RRR-09-006 (Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, June 2009), p. 4.

effectively both day and night, the agency's recently published review[145] of activities underway to develop unobtrusive, in-vehicle, real-time, drowsy driver detection and alertness systems discussed at least five separate systems capable of functioning under a variety of conditions.[146] Therefore, on October 2, 2009, the NTSB classified Safety Recommendation H-08-13 "Open—Unacceptable Response." The NTSB considers that the circumstances of the Miami accident again demonstrate the serious consequences of fatigue-related accidents and the need for in-vehicle technologies to reduce the incidence of such accidents; consequently, the NTSB reiterates Safety Recommendation H-08-13, and the recommendation remains classified "Open—Unacceptable Response."

Vehicle Occupant Survival, Heavy Vehicle Aggressivity

When crashes such as the Miami accident occur, the larger size and greater weight of the heavy commercial vehicle, disproportionate to the smaller, lighter-weight passenger vehicle(s), cause serious injury and often death to the passenger vehicle occupants, due to the larger vehicle's intrusion into the passenger vehicle's occupant compartment, resulting in loss of survivable space. In this accident, the front bumper of the Volvo truck-tractor was higher than the passenger vehicle bumpers and, as a result, the Volvo's bumper and stiffer frame entered the occupant compartments of the passenger vehicles. In the case of the Hyundai and the Kia, the Volvo also drove over the shorter vehicles. Further, the proportional difference in mass between the heavy commercial vehicle (40,400 pounds, unloaded) and the lighter passenger vehicles (the Kia weighed 2,600 pounds) was as high as 15 to 1; this, combined with the speed of the Volvo truck-tractor semitrailer traveling close to 69 mph at impact, compounded the disadvantage for the passenger cars and their occupants. The Volvo's speed contributed to the truck's tremendous kinetic energy at impact, which was dissipated during the collision with the slower moving and stopped passenger vehicles. Because of differences in vehicle weight and structural stiffness, as well as the geometric mismatch of bumper heights, the Volvo truck-tractor's design did not absorb the crash forces from the impact, and the dissipated kinetic energy was transferred to the lighter weight, less stiffer framed passenger vehicles. As a result, these vehicles were catastrophically destroyed.

Due to these factors, survivable space within the first four passenger vehicles struck by the Volvo truck-tractor semitrailer was minimal. Influencing the survivability of a crash for vehicle occupants are several factors: the degree of loss of occupant space, the crash force exerted on each vehicle occupant, and the postcrash environment. Variation in these parameters can result in different outcomes for each vehicle occupant; while one passenger may be killed, another may sustain serious injury, and yet another may walk away uninjured.[147]

[145] L. Barr, S. Popkin, and H. Howarth, *An Evaluation of Emerging Driver Fatigue Detection Measures and Technologies: Final Report*, FMCSA-RRR-09-005 (Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, June 2009).

[146] These five systems are all illumination conditions (from full sunlight to complete darkness), eyeglasses, contact lenses, most sunglasses, and variable subject distances.

[147] W. Spitz, ed., *Spitz and Fisher's Medicolegal Investigation of Death: Guidelines for the Application of Pathology to Crime Investigation*, 3rd edition (Springfield, Illinois: Thomas Publisher, 1993), p. 579.

Consequently, although the Kia sedan's driver and two rear seat occupants (children in booster seats with 3-point restraints) and the Land Rover's rear seat child passenger survived due to the survivable space available to them, the Land Rover's driver and front passenger, all four occupants of the Hyundai, and all four occupants of the Ford Windstar were killed. The NTSB concludes that the combination of the high impact speed of the Volvo truck-tractor semitrailer and the structural incompatibility between the Volvo and the passenger vehicles resulted in extensive intrusion deformation and crush damage to the passenger compartments of the Land Rover, Hyundai, Kia, and Ford Windstar; a loss of survivable space in those vehicles; and the deaths of 10 passenger vehicle occupants.

Occupant protection demands that survivable space be maintained for all passengers and that the interior structure provide sufficient support and energy absorption so that crash forces are survivable. Differences in vehicle weight, stiffness, and structural components (resulting in geometric mismatch) are referred to as "vehicle aggressivity." Vehicles with high aggressivity, such as heavy trucks, often compromise the survivable space within any smaller vehicles they strike, in part because the difference in height between the two vehicles results in override and permits the stiffer elements of the commercial vehicle's front structure to intrude into the passenger vehicle. It is not practical to significantly reduce the weight of a truck-tractor semitrailer or to increase the weight of a passenger vehicle to better match the truck's; consequently, compatibility must be addressed through other means. Deflection of the passenger car and energy absorption into the truck frame might be achieved by design modification, thereby providing some reduction of heavy vehicle aggressivity.[148]

Research conducted in the United States and Europe has focused on ways to improve the outcome when smaller vehicles strike, or are struck by, heavier trucks. Some methods have included matching the geometry of bumper structures, creating energy-absorbing structures[149] to offset the weight differences of the impacting vehicles, and designing the front of the truck to act as a deflector or to redirect[150] the struck vehicle away from the front of the truck, thus reducing the total change in velocity of the smaller vehicle. Europe has adopted standards for front underride protection.[151]

In 1996, research was being conducted to design a new heavy truck bumper with an energy-absorbing honeycomb block, covered by an impact surface that swiveled upon impact, thus deflecting the car away from the truck's path. Testing showed that such a barrier (a prototype of the bumper) deflected the car as desired, with minimum intrusion into the passenger

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[148] See <http://www-nrd.nhtsa.dot.gov/departments/nrd-01/summaries/havp_02.html> (accessed June 10, 2010).

[149] A. Berg and others, "Passive Safety of Trucks in Frontal and Rear-end Collisions With Cars," *Proceedings of the 18th International Technical Conference on Enhanced Safety of Vehicles, Nagoya, Japan* (Washington, DC: National Highway Traffic Safety Administration, 2003).

[150] A. Prasad and others, *Reducing Heavy Truck Aggressivity in Collisions With Passenger Cars*, DOT HS 808 476 (Washington, DC: National Highway Traffic Safety Administration, 1995).

[151] ECE Regulation 93, Part I, "Uniform Provisions Concerning the Approval of Front Underrun Protection Devices."

compartment.[152] However, Volvo has reported that its heavy trucks in the United States do not currently have the FUPSs offered on its European truck models, due to differences in design and weight between European heavy trucks and heavy trucks manufactured, sold, and operated in the North American marketplace. Moreover, there are no U.S. standards or guidelines for equipping heavy trucks with FUPSs.

The NTSB considered this issue during the investigation of an accident involving a tractor semitrailer in Hampshire, Illinois, that rear-ended several vehicles, causing catastrophic damage.[153] In its report on this accident, the NTSB made a recommendation regarding vehicle compatibility to the DOT as follows:

> Include heavy vehicles in your research, testing, and eventual rulemaking on highway vehicle incompatibility, especially as that incompatibility affects the severity of accidents. (H-06-16)

Despite its having been issued 4 years ago, the only update on progress concerning this recommendation received by the NTSB to date has been the DOT's May 2010 transfer of the recommendation to NHTSA, a subordinate agency.

One of the goals of the 21CTP—which comprises multiple Federal government agencies, including several within the DOT, and industry representatives—is to improve truck and bus safety by fostering advancements in vehicle design and performance, such as reducing truck frontal aggressivity in multivehicle collisions. In December 2000, the 21CTP published a "roadmap," which set a milestone of mid-2009 for completing laboratory tests and field trials of systems designed to reduce the destructive effects of truck accidents.[154] Then, in late 2006, the 21CTP published its *Roadmap and Technical White Papers*,[155] which no longer included any milestone date for this project.

The 2006 roadmap document stated that the 21CTP goal is to work collaboratively with DOT-led research programs to determine the feasibility of enhanced occupant survivability in collisions involving large trucks. However, the 21CTP roadmap also stated, "Because transportation safety is the primary mission of the DOT, much of the 21CTP heavy vehicle safety interests will be carried out with the leadership from the DOT." It further stated, "The 21CTP facilitates progress toward the DOT safety goals but does not encompass all the paths to reduced fatalities and injuries."

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[152] K. Mendis and others, "Concepts to Reduce Heavy Truck Aggressivity in Truck-to-Car Collisions," *Proceedings, 15th International Technical Conference on Enhanced Safety of Vehicles, Melbourne, Australia* (Washington, DC: National Highway Traffic Safety Administration, 1996).

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

[154] 21st Century Truck Partnership, *Roadmap and Technical White Papers*, 21CTP-001 (Washington, DC: U.S. Department of Energy, December 2000).

[155] 21st Century Truck Partnership, *Roadmap and Technical White Papers*, 21CTP-0003 (Washington, DC: U.S. Department of Energy, December 2006). For additional information, see <http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/21ctp_roadmap_appendix_2007.pdf> (accessed August 10, 2010).

To date, neither the DOT nor the 21CTP members have completed laboratory tests or field trials in this safety area. NHTSA has not published any information indicating future testing or the intent to implement changes in the industry.

The DOT has discussed the need to reduce fatalities resulting from large truck accidents and has stated that research concerning intelligent transportation system (ITS) technologies for accident avoidance and implementation of such systems are priorities. The NTSB agrees that the deployment of vehicle-based technologies for collision avoidance and mitigation is crucial to highway safety and has issued several recommendations intended to spur progress in this area. In fact, the NTSB considers that collision avoidance systems, such as FCWSs and lane departure warning systems, as well as collision mitigation systems, such as ACC and active braking—which slow down heavy commercial vehicles when a crash is imminent—could significantly increase the effectiveness of heavy vehicle aggressivity countermeasures and provide additional protection to passenger vehicle occupants during collisions between heavy CMVs and passenger vehicles. A multifaceted approach of working to reduce or mitigate heavy vehicle aggressivity while simultaneously studying how collision avoidance and mitigation systems and ITS could help to further decrease passenger vehicle occupant fatalities in such collisions has the greatest likelihood of success. ITS implementation should involve many DOT agencies working in concert, including NHTSA, RITA, the FHWA, and the FMCSA.

The 21CTP has stated that its primary goal is safety and that the use of aerodynamic designs in tractor-trailer construction offers the possibility of making the frontal structures of trucks more complementary and compatible with passenger cars, thereby increasing the likelihood that the occupants of smaller vehicles involved in collisions with trucks may survive. The NTSB concludes that even though heavy truck incompatibility is a major cause of death for occupants of passenger cars, light trucks, and vans involved in crashes with heavy trucks, to date, the DOT and NHTSA have not made this issue a priority and have not allocated sufficient resources to study and address it.

Because of the lack of timely progress by 21CTP members and the DOT in testing systems intended to mitigate the damage caused by truck accidents, the NTSB reclassifies Safety Recommendation H-06-16 to NHTSA "Closed—Unacceptable Action/Superseded" and supersedes H-06-16 with the recommendation that NHTSA, to improve highway vehicle crash compatibility, develop performance standards for FUPSs for trucks with GVWRs over 10,000 pounds. Due to the lack of timely action on the superseded recommendation, this new recommendation is classified "Open—Unacceptable Response." Further, the NTSB recommends that NHTSA, after establishing performance standards for FUPSs for trucks with GVWRs over 10,000 pounds, require that all such newly manufactured trucks be equipped with FUPSs meeting the performance standards.

In the Hampshire report,[156] the NTSB also issued the following safety recommendation to the DOE:

[156] NTSB/HAR-06/03.

> Report to the National Transportation Safety Board the 21st Century Truck Partnership's plans and timetable for prioritizing research, testing, and design enhancements that address heavy truck aggressivity. (H-06-15)

The DOE initially responded that it was "in the process of compiling a report describing the long-range 21CTP goals for truck safety, as well as other research and development activities." It stated in a 2007 update that it anticipated "completion of this report by the end of the current fiscal year, September 30, 2007." The status of Safety Recommendation H-06-15 was "Open—Acceptable Response." However, the DOE has not updated the NTSB on the progress of these efforts since 2007. Therefore, the NTSB reiterates Safety Recommendation H-06-15, and the recommendation is reclassified "Open—Unacceptable Response."

Electronic Data

Event Data Recorders

Although the truck-tractor was equipped with an advanced ECM in combination with an aftermarket Mobius OBC, both of which supported the capture of limited accident-related data, it was not equipped with a dedicated crash EDR, which would have captured vital crash information and allowed for a significantly higher level of science to be applied to the NTSB's investigation and analysis of this accident. A dedicated crash EDR intended to assist in collision reconstruction and analysis would have captured both operator and vehicle-based data just before and during the crash sequence. A dedicated EDR, specifically intended for crash data retrieval following a crash event, can provide critical high-resolution performance data concerning driver, vehicle, and safety systems. To enhance crash testing with real-world data, data from vehicle crashes must be available for analysis.

During the 2007 SAE symposium on highway EDRs,[157] industry representatives reported that many motor carrier operators currently use vehicle data recorders. However, the Miami accident truck-tractor was not equipped with a dedicated or more sophisticated EDR that would have provided additional parameters and precision data regarding both driver and vehicle dynamics throughout the accident sequence. Crash pulses[158] and/or Delta V are often used to calculate vehicle occupant kinematics, help evaluate injury exposure, and assess the effectiveness of passenger protection and safety devices and systems. Using these data, investigators and engineers can predict potential injury mechanisms and assess the effects of various design elements on occupant protection systems and vehicle designs for crash mitigation.

In addition, EDR data can be used to enhance the development of advanced technologies for the manufacture of truck cab, frontal, and side structures. The data can contribute to the

[157] Highway Vehicle Event Data Recorder Symposium, September 5–6, 2007 (Ashburn, Virginia: SAE International, 2007).

[158] The term "crash pulse" refers to acceleration versus time history. It may be more helpful to think in terms of crash forces, because the forces to which a vehicle is subjected as a result of a collision are a direct function of the crash pulse.

development of computer models to verify the energy-absorption capabilities of heavy-duty vehicles and be used in studies on frontal-structure aggressivity. They can also advance the use of finite element and occupant kinematic analyses of candidate structural designs to identify optimized designs and assist in determining the capacity of sandwich, cored, and foam materials for energy-absorption applications.[159]

Large truck design may affect the severity of trauma sustained by occupants of all vehicles—whether heavy or not—involved in a heavy vehicle crash. Vehicle design and performance attributes are important concerns; optimized design may improve large truck safety and help reduce truck-crash-related fatalities. Although crash forces may be estimated by comparing an accident vehicle's physical damage to that of instrumented crash test data, this method is not always reliable. This unreliability, coupled with the lack of availability of heavy vehicle crash test data, makes the collection of real-world data crucial to researchers and design engineers.

A lack of useful event data associated with the Miami accident represents another missed opportunity to better understand the crash forces and crashworthiness issues involved when heavy vehicles strike other vehicles. The NTSB concludes that the heavy truck in the Miami accident lacked a dedicated EDR designed for accident reconstruction and to provide accelerometer-based crash pulse data, which are critical to the evaluation of vehicle performance and could have been used in vehicle incompatibility research; therefore, these data are again unavailable to investigators and researchers.

The NTSB considers that adequate on-board recording devices are necessary in all modes of transportation because information from them can be used to identify safety trends, develop corrective actions, and conduct more efficient and precise accident investigations. Cockpit voice recorders and flight data recorders, commonly referred to as black boxes, have been required on commercial airliners for decades. Since 1993, event recorders have also been required on trains. In marine transportation, voyage data recorders are now required on all international passenger and cargo ships.

The NTSB has also made previous recommendations regarding recorders for highway trucking transport. Although the recommendation was primarily aimed at reducing fatigue-related accidents, in 1990,[160] the NTSB recommended that the FHWA:

> Require automated/tamper-proof on-board recording devices, such as tachographs or computerized logs, to identify commercial truck drivers who exceed hours-of-service regulations. (H-90-28)

The NTSB reiterated Safety Recommendation H-90-28 in its 1995 study on truck driver fatigue,[161] explaining that the intent of the recommendation was to provide a tamper-proof mechanism that could be used to enforce the HOS regulations, rather than relying on drivers' handwritten logs. In a February 1997 response, the FHWA acknowledged that on-board

[159] *Roadmap and Technical White Papers*, 21CTP-001.

[160] NTSB/SS-90/01.

[161] NTSB/SS-95/01.

recording devices would eventually be an important tool for monitoring the HOS of CMV drivers. However, the FHWA stated that "the FHWA position is that the benefits and practicality of on-board recorders must be firmly established before rulemaking ensues." In 1997, the NTSB classified Safety Recommendation H-90-28 "Closed—Unacceptable Action" due to the lack of positive action by the FHWA.

In 1998, as the result of an accident investigation involving two truck-tractor semitrailer vehicles in Slinger, Wisconsin,[162] the NTSB recommended that the ATA, the Motor Freight Carriers Association, the International Brotherhood of Teamsters, the Independent Truckers and Drivers Association, the National Private Truck Council, and the Owner-Operator Independent Drivers Association, Inc., advise their members to equip their commercial vehicle fleets with automated and tamper-proof on-board recording devices, such as tachographs or computerized recorders, to identify information concerning both driver and vehicle operating characteristics (Safety Recommendations H-98-23 and -26). In 2001, both recommendations were classified "Closed—Unacceptable Action."

The NTSB has also made recommendations to NHTSA concerning EDRs in heavy commercial vehicles that carry passengers, specifically, school buses and motorcoaches. In 1999, the NTSB issued the following two recommendations to NHTSA as a result of a special investigation report on bus crashworthiness:[163]

> Require that all school buses and motorcoaches manufactured after January 1, 2003, be equipped with on-board recording systems that record vehicle parameters, including, at a minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left/right), brake light status (on/off), head/tail light status (on/off), passenger door status (open/closed), emergency door status (open/closed), hazard light status (on/off), brake system status (normal/warning), and flashing red light status (on/off) (school buses only). For those buses so equipped, the following should also be recorded: status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy. The on-board recording system should record data at a sampling rate that is sufficient to define vehicle dynamics and should be capable of preserving data in the event of a vehicle crash or an electrical power loss. In addition, the on-board recording system should be mounted to the bus body, not the chassis, to ensure that the data necessary for defining bus body motion are recorded. (H-99-53)
>
> Develop and implement, in cooperation with other government agencies and industry, standards for on-board recording of bus crash data that address, at a minimum, parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid immersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances. (H-99-54)

[162] *Multiple Vehicle Crossover Accident, Slinger, Wisconsin, February 12, 1997,* Highway Accident Report NTSB/HAR-98/01 (Washington, DC: National Transportation Safety Board, 1998).

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

The NTSB reiterated Safety Recommendation H-99-53 in its report on a 2007 motorcoach ramp override accident in Atlanta, Georgia, that killed seven passengers.[164] In that report, the NTSB determined that EDR data would have yielded information on vehicle parameters and driver actions prior to the accident, as well as on vehicle dynamics throughout the accident sequence, which would have been valuable in reconstructing and evaluating occupant kinematics, injury exposure, and the potential benefits of occupant protection devices and systems. Safety Recommendations H-99-53 and -54 were reiterated in the NTSB's 2009 special investigation on pedal misapplication in heavy vehicles, a report that focused primarily on school buses.[165] The NTSB concluded that the presence of EDRs in heavy vehicles would provide essential and specific information regarding the causes and mechanisms of pedal misapplication and claims of unintended acceleration. Safety Recommendations H-99-53 and -54 were classified "Open—Unacceptable Response" because of NHTSA's failure to require the use of EDRs on buses.

Most recently, in its report on a motorcoach rollover accident in Dolan Springs, Arizona,[166] the NTSB concluded that the availability of recorded event data would have resulted in a more complete account of the preaccident events leading to the rollover. In addition, the NTSB found that having EDRs on all buses above 10,000 pounds GVWR would greatly increase the understanding of crash causation and be helpful in further establishing design requirements for crashworthiness and occupant protection systems. Therefore, the NTSB superseded Safety Recommendation H-99-53 with the following recommendation to NHTSA:

> Require that all buses above 10,000 pounds gross vehicle weight rating be equipped with on-board recording systems that: (1) record vehicle parameters, including, at minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left/right), brake light status (on/off), head/tail light status (on/off), passenger door status (open/closed), emergency door status (open/closed), hazard light status (on/off), brake system status (normal/warning), and flashing red light status (on/off; school buses only); (2) record status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy; (3) record data at a sampling rate sufficient to define vehicle dynamics and be capable of preserving data in the event of a vehicle crash or an electrical power loss; and (4) are mounted to the bus body, not the chassis, to ensure recording of the necessary data to define bus body motion. (H-10-7)

Safety Recommendation H-99-53 specified that EDRs be required for school buses and motorcoaches; and, by superseding Safety Recommendation H-99-53 with H-10-7, the NTSB recognized that EDRs should be required for all buses over 10,000 pounds GVWR. As illustrated by the Miami accident, EDR data would also be very useful with respect to accidents involving heavy vehicles, by permitting the reconstruction of preaccident events and the evaluation of

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

[165] *Pedal Misapplication in Heavy Vehicles*, Highway Special Investigation Report NTSB/SIR-09/02 (Washington, DC: National Transportation Safety Board, 2009).

[166] *Bus Loss of Control and Rollover, Dolan Springs, Arizona, January 30, 2009*, Highway Accident Report NTSB/HAR-10/01 (Washington, DC: National Transportation Safety Board, 2010).

crash dynamics for both heavy vehicles, such as truck-tractors, and any involved passenger vehicles.

In addition to pressing for EDRs to be installed on heavy vehicles, the NTSB has advocated EDRs for light vehicles. In its 2004 report on the Santa Monica, California, farmer's market accident,[167] the Board issued Safety Recommendation H-04-26, asking NHTSA to require light vehicles to be equipped with EDRs. On August 28, 2006, NHTSA published a final rule establishing performance standards for voluntarily installed EDRs. As a result of manufacturers voluntarily equipping most of their light vehicles with EDRs, the NTSB classified Safety Recommendation H-04-26 "Closed—Acceptable Alternate Action." Although NHTSA has made progress in developing EDR standards for light vehicles (such as publishing a final rule addressing the survivability requirements and information to be collected by EDRs for light vehicles), there is still no requirement for the installation and use of light vehicle EDRs. Further, NHTSA has not developed standards nor required the use of EDRs for heavy commercial vehicles, including motorcoaches, school buses, and truck-tractor semitrailer units.

Establishing EDR performance standards for heavy highway vehicles is necessary to create a foundation for the timely and efficient incorporation of EDRs into such vehicles. Without such required standards, the heavy vehicle industry will continue to operate without reasonable guidelines or requirements regarding what EDR technology should be installed and what data the EDR should collect. NHTSA should develop EDR standards for all heavy vehicles, not just motorcoaches and school buses, because the lack of data from non-passenger-carrying heavy vehicles deprives researchers of valuable crash data needed to develop crashworthiness and design applications affecting heavy vehicles and other vehicles that may be involved in a heavy vehicle crash. Neither NHTSA nor the FMCSA defines light or heavy vehicles, although the FMCSA's definition for a CMV includes a vehicle weighing 10,001 pounds or more (per 49 CFR 390.5).[168] The NTSB considers that EDR standards and the requirement that they be used, such as recommended for school buses and motorcoaches (in Safety Recommendations H-99-53 and H-10-7), should apply to all heavy highway vehicles. Thus, future postaccident data for these types of vehicles would provide a more complete and accurate record of the crash pulse and vehicle dynamics involved in heavy highway vehicle crashes.

Therefore, the NTSB concludes that due to the lack of government standards and requirements for the design and use of highway vehicle EDRs, valuable high-fidelity crash data continue to go unrecorded and, thus, are unavailable for analysis. The NTSB recommends that NHTSA develop and implement minimum performance standards for EDRs for trucks with GVWRs over 10,000 pounds that address, at a minimum, the following elements: data parameters to be recorded; data sampling rates; duration of recorded event; standardized or

[167] *Rear-End Collision and Subsequent Intrusion Into Pedestrian Space at Certified Farmer's Market, Santa Monica, California, July 16, 2003*, Highway Accident Report NTSB/HAR-04/04 (Washington, DC: National Transportation Safety Board, 2008).

[168] "Commercial motor vehicle" refers to any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle: (1) has a GVWR or gross combination weight rating, or gross vehicle weight or gross combination weight of 10,001 pounds or more, whichever is greater; or, (2) is designed or used to transport more than 8 passengers (including the driver) for compensation; or, (3) is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation.

universal data imaging interface; data storage format; and device and data survivability for crush, impact, fluid exposure and immersion, and thermal exposure. The standards should also require that the EDR be capable of capturing and preserving data in the case of a power interruption or loss, and of accommodating future requirements and technological advances, such as flashable and/or reprogrammable operating system software and/or firmware updates. The NTSB also recommends that NHTSA should, after establishing performance standards for EDRs for trucks with GVWRs over 10,000 pounds, require that all such vehicles be equipped with EDRs meeting the standards.

Video Event Recorders

The data gathered by the NTSB during this investigation strongly indicated that a loss of driver alertness due to fatigue was the most likely cause of this accident. However, given the limited information available, this could not be confirmed with certainty. Thus, driver distraction could not be ruled out.

A 2009 NHTSA report, *An Examination of Driver Distraction as Recorded in NHTSA Databases*, stated that, in 2008, about 5,870 people lost their lives and an estimated 515,000 people were injured in police-reported crashes in which at least one form of driver distraction appeared on the accident report. NHTSA further asserted that, "While these numbers are significant, they may not state the true size of the problem, since the identification of distraction and its role in the crash by law enforcement can be very difficult."[169] It has been estimated that 80 percent of all crashes and 65 percent of near-crashes involve some type of driver inattention.[170] Distraction is one form of inattention; and, according to NHTSA FARS data, driver distraction was reported to have been involved in 16 percent of all fatal crashes in 2008. According to NHTSA's General Estimates System information, an estimated 21 percent of injury crashes involve distracted driving.[171]

One possible solution to the problem of driver distraction may be the VER, a device designed to capture video and other parameters related to operator and vehicle performance. A VER may record forward-looking video, interior video, interior audio, lateral acceleration, and longitudinal acceleration. VER systems may be configured to save the video and other data after a triggering event is detected. VER manufacturers offer systems for use in private, public, and commercial vehicles.

For commercial vehicle use, the systems are marketed as tools to reduce operating and insurance costs while increasing safety, by allowing companies to monitor and modify driver behavior. With respect to operating and insurance costs, companies using these systems have

[169] *An Examination of Driver Distraction as Recorded in NHTSA Databases*, DOT HS 811 216 (Washington, DC: NHTSA National Center for Statistics and Analysis, September 2009). See <http:www-nrd.nhtsa.dot.gov/Pubs/811216.pdf> (accessed June 7, 2010).

[170] See <http://www.trb.org/Main/Blurbs/100Car_Naturalistic_Driving_Study_155990.aspx> (accessed September 21, 2010).

[171] *An Examination of Driver Distraction as Recorded in NHTSA Databases*, DOT HS 811 216.

reported reduced fuel consumption, fewer collisions, and insurance claims savings.[172] Concerning safety, the companies report reductions in collisions, vehicle damage, and injury/worker's compensation claims.

In January 2008, the NTSB investigated an accident near Mexican Hat, Utah, in which the involved motorcoach was equipped with a VER.[173] The information from the VER allowed investigators to document vehicle motion, use of headlights, driver actions, and passenger statements and reactions. Because of the information recorded by the VER on the Mexican Hat motorcoach, investigators were able to determine that the driver was driving too fast (23 mph above the posted speed limit of 65 mph) and was not distracted or using a cellular telephone. The VER provided verified information unavailable by other means and helped prove that the accident was caused by the driver's diminished alertness.

As noted earlier in this report, the FMCSA evaluated VERs in its driving behavior management system study.[174] VERs were installed in the fleets of two commercial carriers. During the study's evaluation phase, data collected from the VERs were sent to the system provider for review, and safety-related events were forwarded to the carrier management so an "intervention" could be conducted. An intervention consisted of the manager and driver watching the video, discussing the cause, and determining followup steps (training, discipline, reward, etc.) to prevent future issues. The results from the two carriers indicated a reduction in safety-related events per 10,000 miles of over 38 percent at one carrier and over 52 percent at the other. In addition, severe safety-related incidents decreased by more than 59 percent and 44 percent, respectively. Based on the study results, the NTSB concludes that VERs have the potential to increase safe behavior among commercial drivers through structured safety performance monitoring, which may lead to decreases in accidents and injuries.

On March 19, 2009, the FMCSA issued a notice of final disposition and granted a 2-year exemption to Greyhound Lines, Inc., to enable the company to mount VERs on its buses lower in the windshield than is currently permitted by Federal regulations. According to the FMCSA, Greyhound requested the exemption so that the company could use the VERs to increase safety through (1) identification and remediation of risky driving behaviors, such as distracted driving and drowsiness; (2) enhanced monitoring of passenger behavior; and (3) enhanced collision review and analysis. One of the reasons that the FMCSA granted the exemption to Greyhound was that it "believes that the potential safety gains from the use of video event recorders to improve driver behavior will improve the overall level of safety to the motoring public."[175]

According to one VER system provider, 120,000 vehicles are currently equipped with its recorders. The system designs continue to be refined and improved to resolve problems. For

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172 See <http://www.roadscan.co.uk/roadscanvideos/index.php> (accessed February 3, 2010) and <http://www.drivecam.com> (accessed February 3, 2010).

173 *Motorcoach Rollover Near Mexican Hat, Utah, January 6, 2008*, Highway Accident Report NTSB/HAR-09/01 (Washington, DC: National Transportation Safety Board, 2009).

174 See <http://www.fmcsa.dot.gov/facts-research/research-technology/tech/FMCSA-RRR-10-032.pdf> (accessed September 23, 2010) and <http://www.fmcsa.dot.gov/facts-research/media/webinar-09-07-22-slides.pdf> (accessed February 3, 2010).

175 *Federal Register*, vol. 74, no. 52 (March 19, 2009), pp. 11807–11808.

example, the VER's memory capacity as installed is limited; older events are deleted as new ones occur. To see a reduction in the triggered events, as well as the history of triggering behaviors, information must be available for each triggered event. Thus, to some extent, a VER system's usefulness depends on the availability of triggered event data over time.

Some drivers and carriers have doubts and concerns about the implications of VER use. For example, NTSB staff contacted one carrier evaluating the system, and its representative mentioned having problems with "false positives"—actions that appeared to be unsafe but were later determined to be acceptable. (VER system providers continue to adjust the systems to increase their accuracy.)[176]

Driver privacy is another commonly expressed concern. VER system providers have attempted to allay drivers' concerns by emphasizing the benefits that drivers can obtain when VERs are in use. For instance, if the driver drives safely, no recording will be triggered; however, the driver can choose to activate the VER (by pressing a button) to record unsafe actions committed by others. Thus, the driver can use the system to validate his/her self-reported statements of safe driving behavior and to counter any allegations of improper action, should this be necessary. In the event of a crash or other major safety incident, a VER can provide proof that the driver was not at fault.

As demonstrated by the Mexican Hat accident investigation, VERs can provide information not typically available through other investigative means, potentially allowing a more accurate determination of probable cause. In the case of the Miami accident, a forward-looking video could have provided investigators more information on the actions of the vehicles ahead of the accident truck and their visibility, and an interior video could have allowed investigators to entirely rule out medical incapacitation or distraction and identify periods of reduced vigilance. The NTSB concludes that had the accident truck been equipped with a VER, a more definitive assessment of the driver's precrash condition and behavior would have been possible.

The NTSB has long advocated the use of recording devices as a means of quantifying operator and vehicle behaviors in other modes of transportation.[177] NTSB investigations have benefitted from the presence of data, video, and audio recorders in most modes of transportation, and it is evident from FMCSA-funded research that VER data are being used on a routine basis by transportation safety managers to reduce risky behaviors by their drivers through structured safety-performance-monitoring programs.

Another benefit of using VERs for monitoring operator behavior and providing accident information has been demonstrated in the FOTs for FCWSs and the research tests of IVBSS. Such safety systems rely heavily on driver perception and reaction times to provide the best warning and alerting intervals for accident prevention. Additional information on driver behaviors provided by an increased volume of VER data could be used to help improve these

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[176] Per NTSB staff telephone interview with DriveCam company vice president for product management, February 9, 2010.

[177] For example, see NTSB Safety Recommendations R-81-65, R-81-67, R-84-38, R-87-21, R-90-17, M-95-5, M-95-6, H-07-41, A-07-7, A-09-90, R-10-1 and -2, A-10-27, and A-10-29.

systems. Anecdotal evidence of savings in fuel and insurance costs also suggests that CMV carriers could benefit financially by installing and using VERs throughout their fleets. Drivers, too, could benefit by using the systems to provide evidence of their safe driving behavior.

The Miami accident investigation shows not only the value of having scientific, unbiased data available when investigating and reconstructing highway transportation accidents but also the value of having video-based event data to correlate with analog and digital EDR data to establish a driver's condition and state of attention. Heavy commercial vehicle industry members could also realize safety, cost, and other benefits by installing VERs in all their vehicles. Therefore, the NTSB recommends that the FMCSA require all heavy commercial vehicles to be equipped with VERs that capture data in connection with the driver and the outside environment and roadway in the event of a crash or sudden deceleration event. The device should create recordings that are easily accessible for review when conducting efficiency testing and systemwide performance-monitoring programs. Further, the NTSB recommends that the FMCSA require motor carriers to review and use VER information in conjunction with other performance data to verify that driver actions are in accordance with company and regulatory rules and procedures essential to safety.

Forward Collision Warning Systems

General

Rear-end crashes occur when the front of a following vehicle strikes the rear of a lead vehicle. FARS data show that from 2001 to 2009, 1,453 fatalities occurred in 2-vehicle rear-end collisions involving a large truck rear-ending a passenger vehicle(s). In 2008, one out of nine traffic fatalities resulted from a collision involving a large truck. That year, about 380,000 large trucks were involved in traffic crashes in the United States, and 4,066 were involved in fatal crashes. A total of 4,229 people died (11 percent of all the traffic fatalities reported in 2008) and an additional 90,000 were injured in those crashes.[178] In 2009, 3,380 people died in crashes that involved a large truck.[179] Because rear-end crashes resulting from heavy vehicles tend to be more catastrophic, due to the extreme force of impact these vehicles may cause,[180] the NTSB has been exploring technical solutions for preventing rear-end collisions for at least 15 years.

[178] See <http://www-nrd.nhtsa.dot.gov/Pubs/811158.pdf> (accessed June 22, 2010).

[179] See <http://www-nrd.nhtsa.dot.gov/Pubs811363.pdf> (accessed September 16, 2010).

[180] A. Hesham and others, *Safety Benefit Evaluation of a Heavy Vehicle Forward Collision Warning System*, paper 10-0207 presented at the January 10–14, 2010, Transportation Research Board 89th Annual Meeting in Washington, D.C.

The NTSB first discussed FCWS technology in a 1995 report concerning an investigation of a highway accident that occurred in fog in Menifee, Arkansas.[181] In the Menifee accident report, the NTSB recommended, via Safety Recommendation H-95-44, that the DOT,

> In cooperation with the Intelligent Transportation Society of America, sponsor 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. (H-95-44)

Due to the time elapsed since the recommendation's issuance and noting that industry had taken the lead in implementing the technology, the NTSB classified Safety Recommendation H-95-44 "Closed—Unacceptable Action" on August 10, 1999.

The NTSB also focused on the issue of technology in a 2001 special investigation report that addressed the findings from a 1999 public hearing on "Advanced Safety Technologies for Commercial Vehicle Applications."[182] The 1995 Menifee report and the 2001 special investigation discussed how technology, in the form of ITS, can be used to prevent rear-end collisions.

In the 9 years since the special investigation report on technology was published, the NTSB has investigated 9 rear-end collisions (including the Miami accident), in which 39 people died and 124 were injured.[183] In addition, the NTSB investigated the Osseo motorcoach accident, in which another vehicle was blocking the roadway and the motorcoach struck the underside of the overturned vehicle head-on.[184] In this accident, 5 people were killed and 36 were injured. In all, these 10 accidents involved truck-tractor semitrailers, motorcoaches, school buses, and passenger vehicles. (See table 6.)

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

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

[183] (a) *Work Zone Collision Between a Tractor-Semitrailer and a Tennessee Highway Patrol Vehicle, Jackson, Tennessee, July 26, 2000*, Highway Accident Report NTSB/HAR-02/01 (Washington, DC: National Transportation Safety Board, 2002). (b) *Collision of a Greyhound Lines, Inc., Motorcoach and Delcar Trucking Truck-Tractor Semitrailer, Loraine, Texas, June 9, 2002*, Highway Accident Report NTSB/HAR-03/01 (Washington, DC: National Transportation Safety Board, 2003). (c) NTSB/HAR-06/03. (d) *Rear-End, Chain Reaction Collisions at U.S. Border Patrol Checkpoint, Interstate Highway 87 Near North Hudson, New York, February 22, 2004, and September 19, 2004*, Highway Accident Brief NTSB/HAB-05/03 (Washington, DC: National Transportation Safety Board, 2005). (e) *Rear-End Chain Reaction Collision, Interstate 30 West, Near Sulphur Springs, Texas, June 13, 2004*, Highway Accident Brief NTSB/HAB-08/02 (Washington, DC: National Transportation Safety Board, 2008). (f) *Rear-End Chain Reaction Collision, Interstate 94 East, Near Chelsea, Michigan, July 16, 2004,* Highway Accident Brief NTSB/HAB-07/01 (Washington, DC: National Transportation Safety Board, 2007). (g) *Rear-End Chain-Reaction Collision, State Route 121, Near Lake Butler, Florida, January 25, 2006,* Highway Accident Brief NTSB/HAB-08/05 (Washington, DC: National Transportation Safety Board, 2008).

[184] NTSB/HAR-08/02.

Table 6. Relevant collisions investigated by the NTSB since the issuance of the special investigation report on technologies for the prevention of collisions (NTSB/SIR-01/01).

Year	Accident	Crash Type	Fatalities	Injuries
2000	Jackson, TN	Tractor-semitrailer struck highway patrol vehicle	1	1
2002	Loraine, TX	Motorcoach struck truck-tractor semitrailer	3	31
2003	Hampshire, IL	Truck-tractor combination unit struck specialty bus, leading to multivehicle chain-reaction collision	8	15
2004	North Hudson, NY (February)	Motorcoach struck truck-tractor semitrailer, leading to multivehicle chain-reaction collision (border crossing queue)	0	53
2004	North Hudson, NY (September)	Tractor-semitrailer struck passenger car, leading to multivehicle chain-reaction collision (border crossing queue)	4	3
2004	Sulphur Springs, TX	Tractor-auto transporter struck passenger vehicle, leading to chain-reaction collision	5	2
2004	Chelsea, MI	One truck-tractor semitrailer struck another, which then struck passenger vehicle	1	2
2005	Osseo, WI	Truck-tractor semitrailer rolled over, leading to motorcoach collision with overturned truck	5	36
2006	Lake Butler, FL	Truck-tractor combination unit struck passenger vehicle, which then struck school bus	7	11
2009	Miami, OK	Tractor-semitrailer struck passenger vehicle, leading to multivehicle chain-reaction collision	10	6
		TOTAL	44	160

Common to each of these NTSB-investigated accidents was the crucial circumstance that the following vehicle driver had a degraded perception of traffic conditions ahead. During its investigation of these collisions, the NTSB examined the striking vehicles and found no mechanical defects that would have contributed to the accidents. Also, in each case, the driver of the striking vehicle tested negative for alcohol and drugs. Some of these collisions occurred because atmospheric conditions, such as nighttime darkness or smoke, interfered with the driver's ability to detect slower moving or stopped traffic ahead. In other cases, the drivers did not notice that traffic had come to a halt due to other accidents, tollbooths, congestion at work zones, and even school buses dropping off students. Still others involved drivers who were distracted or fatigued. Regardless of the individual circumstances, the striking vehicle drivers in these accidents were unable to detect slowed or stopped traffic ahead and to stop their vehicles in time to prevent a rear-end collision.

FCWSs utilize radar-based technology or, more recently, camera-based systems with vehicle detection algorithms, to recognize images of motorized vehicles. Both types of FCWSs provide audible and visual alerts to warn the driver when other vehicles or stationary objects are within predefined distances or closing speeds in the forward path of the vehicle. FCWSs began to appear as safety devices on large trucks in the 1990s.[185] FCWSs currently on the market can detect objects at distances of up to 500 feet[186] and display warnings at distances of up to 350 feet or at calculated following distance periods of up to 3.00 seconds. The FMCSA has collaborated with the trucking industry to test and evaluate these systems, has defined voluntary operational requirements, and is now promoting voluntary adoption of these systems within the trucking industry. Although FCWSs are established technologies available on newly manufactured truck-tractors, the 2008 model year Volvo truck-tractor involved in this accident was not equipped with an FCWS. No regulations currently mandate the use of FCWS technology, but many carriers have chosen to install and use such systems voluntarily throughout their fleets.

In its 2001 special report on technology for the prevention of rear-end crashes,[187] the NTSB reported that, in 1999, the DOT had begun operational testing of ACC systems and FCWSs for cars and trucks. The NTSB also reported that rear-end collisions accounted for 1.8 million crashes in 1999, including 1,923 fatal crashes. Of the fatal crashes, 770 involved commercial vehicles (trucks weighing more than 10,000 pounds and motorcoaches). Thus, CMVs were involved in 40 percent of the fatal rear-end crashes, even though they accounted for only 3 percent of vehicles and 7 percent of miles traveled. Although the NTSB has acknowledged that an FCWS is not intended to replace driver vigilance, such a system can aid drivers when they are distracted or fatigued, or when their attention is concentrated on something other than the road ahead. The NTSB concluded that accident statistics and the investigation findings indicate that accident consequences are more severe when commercial vehicles are involved in rear-end collisions and that the public can benefit from technology designed to help prevent such collisions. As a result, in its special report, the NTSB asked the DOT[188] to take the following actions:

> 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-01-6)
>
> After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system. (H-01-7)

Safety Recommendation H-01-6 is on the NTSB Most Wanted List of Transportation Safety Improvements in the issue area “Prevent Collisions by Using Enhanced Vehicle Safety Technology.” Deployment of vehicle collision avoidance technology has been on the Most Wanted List since November 2007.

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[185] The VORAD system, previously owned by Eaton and now owned by Bendix, was introduced in 1995.

[186] The Bendix VORAD VS-400 detects vehicles in the same lane within 350 feet of the radar. The Meritor WABCO OnGuard system detects and tracks vehicles up to 500 feet in front of the host vehicle. Vehicle images in the camera-based system from Mobileye enter the detection range approximately 328–394 feet in front of the host vehicle.

[187] NTSB/SIR-01/01.

[188] These recommendations were originally assigned to the FMCSA; the DOT subsequently transferred them to NHTSA.

In the Miami accident, an FCWS alert could have drawn the accident driver's attention to the hazard ahead, which was the slowing traffic. The truck-tractor semitrailer was traveling about 103 feet per second. With the maximum available warning detection distance of 350 feet provided by an FCWS, the Miami accident driver would have received a warning from the system about 3.40 seconds before striking the rear of the slowly moving traffic queue. Within this 3.40-second warning period, the driver would have to have (1) been effectively alerted; (2) comprehended the severity of the alert and the situation ahead; and (3) mechanically executed a reaction, including moving his foot from its rest location (the cruise control was engaged) and placing it on the brake and applying maximum (emergency) braking immediately. If any time (and distance) had remained from the 3.40 seconds after (1) through (3) above, it could have gone toward slowing the vehicle or enabling the driver to take an evasive action to mitigate the impact force of the tractor semitrailer upon the passenger vehicles.[189]

It should be noted that, for an alert driver,[190] the average projected reaction time to an unexpected situation can range from 0.75 second to about 2.50 seconds for a 90th percentile driver.[191,192] Research supports that, in the middle of this range, drivers have a perception reaction time to a common but unexpected stimulus (such as the unanticipated brake lights of a car ahead) of about 1.25 seconds.[193] Given a reasonably clear and straightforward situation, most drivers will respond within 1.50 seconds of the first appearance of an object or condition of concern;[194] they will react to a surprise event (such as an object moving unexpectedly into the vehicle's path) in 1.50 to 1.75 seconds.[195]

Some FCWSs are equipped with ACC,[196] which uses the same detection technology as the FCWS to adjust or disengage the conventional cruise control when it is in use. An active braking system that can automatically apply the foundation brakes[197] of the vehicle is also an available technology. If a collision is deemed imminent, an FCWS with active braking does not wait for the driver to react; in such a critical situation, braking is applied automatically to reduce the severity of the impending collision. Once active braking is initiated to mitigate the accident

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189 Perception time/distance + physical reaction time/distance + brake lag time/distance + effective braking time/distance = total stopping distance.

190 FCWS manufacturers acknowledge that their systems are designed to aid alert and conscientious drivers; such systems will not necessarily compensate for driver impairments, such as fatigue.

191 Brake reaction time includes the time it takes for the driver to see the object and to recognize it as stationary or slow moving against the background of the roadway and other objects, such as walls, fences, trees, poles, or bridges. AASHTO considers minimum brake reaction times to be between 1.64 and 3.50 seconds, and the recommended design criterion of 2.50 seconds for brake reaction time exceeds the 90th percentile of reaction time for all drivers, considered by AASHTO as adequate for more complex situations.

192 M. Green, "How Long Does It Take To Stop? Methodological Analysis of Driver Perception-Brake Times," *Transportation Human Factors*, vol. 2, no. 3 (2000), pp. 195–216.

193 M. Green, pp. 195–216.

194 R. Dewar and P. Olson, *Human Factors in Traffic Safety* (Tucson, Arizona: Lawyers and Judges Publishing Co., 2001).

195 M. Green, pp. 195-216.

196 The systems are sometimes bundled together in a package.

197 According to the Bendix *Airbrake Handbook* (2004), the foundation brake is the actual braking mechanism located at each end of the axle. It generally consists of an air or spring brake chamber (with slack for S-cam) and a mechanical brake mechanism, including the friction material.

(not when initiated to slow the vehicle to maintain following distance, such as with the ACC), it also may be referred to as "collision mitigation braking" or CMB. When these technologies are bundled together, they are often referred to as "collision mitigation systems." If the Miami accident truck had been equipped with an FCWS that included an active braking system, the driver's reaction time would not have been a factor—only the brake lag time would have contributed to the distance traveled before maximum braking was achieved.

An FCWS alone or bundled with ACC and active braking could have significantly affected the outcome of the Miami accident, depending on a number of factors, including the point at which the system detected the Land Rover ahead of it. The unloaded truck-tractor semitrailer had a gross weight of 40,400 pounds (a loaded truck-tractor semitrailer can weigh up to 80,000 pounds). Most cars weigh less than 4,000 pounds. Thus, when a commercial truck strikes a passenger car in the rear, the large difference in mass between the vehicles means that this impact most likely will not bring the heavy truck to a stop or even slow it appreciably; consequently, the impact itself does relatively little to keep the truck from continuing to move and to involve more vehicles.[198] An FCWS can reduce the risk of these rear-end crashes by identifying fast-closing speed situations and providing the driver with additional time to react. It should be noted that ACC systems are designed to maintain a predetermined[199] following interval behind another vehicle, thereby providing more time to resolve driving conflicts to reduce the probability of a rear-end collision.[200]

An FCWS with active braking can begin to decelerate a vehicle automatically, having the added benefit either of reducing the speed of the vehicle if the driver does not intervene or of supplementing deceleration before the driver applies braking. Active braking systems, such as the Bendix Wingman ACB (active braking with cruise control) and the Meritor WABCO OnGuard, do not apply the foundation brakes at the full emergency brake application level that a driver can.

FCWS Scenarios

To illustrate some possible scenarios for this accident under different circumstances, the NTSB worked with several FCWS manufacturers[201] and developed some potential outcomes had the accident truck been equipped with an FCWS alone or bundled with ACC and/or active braking. Three of the possible outcomes are presented below. NTSB investigators were unable to determine the speed of the Land Rover just prior to its being struck by the Volvo; therefore, the first two of the following scenarios are based on witness interviews indicating either that the struck vehicles were stopped in traffic or that the Land Rover was moving slowly (just over 10 mph). The third instance is the "best case" scenario, in which the Land Rover was just beginning

[198] R. Craft, FMCSA Paper: *Rear-End Large Truck Crashes*, 2002. See <http://www.fmcsa.dot.gov/facts-research/briefs/rear.pdf> (accessed July 20, 2010).

[199] The manufacturer sets a default following interval, or the carrier or driver can set it.

[200] See <http://www.fmcsa.dot.gov/facts-research/research-technology/report/forward-collision-warning-systems.htm> (accessed June 22, 2010).

[201] Bendix VORAD, Meritor WABCO, and Mobileye.

to decelerate from the posted speed limit of 75 mph when the Volvo FCWS detected it at 70 mph, with the Volvo 350 feet or more behind it.

All calculations in the scenarios and tables below considered a roadway coefficient of 0.65 g deceleration for the Volvo and an initial truck speed of about 70 mph. They also assumed the postaccident inspection condition of the brakes, which were within adjustment limits, on the truck-tractor semitrailer. An air brake lag time of 0.50 second was used, in addition to the driver perception reaction times of 2.50, 1.50, and 0.75 seconds. The term “distance to decelerate” used in the tables below is the distance between the accident truck-tractor and the Land Rover when the truck driver receives the first FCWS alert. The “warning time” is the time the truck driver would have between the first FCWS alert and the estimated impact.

Scenario 1—FCWS and Land Rover Stopped. Had the Land Rover, the first vehicle struck by the Volvo truck, been stopped (stationary) in the traffic queue, an FCWS on the Volvo could have detected it at either 308 or 350 feet,[202] calculated the closing distance, and sounded an audible alert. Table 7 shows the reductions in impact speeds possible, had the Volvo truck driver perceived the meaning of the alert and reacted, given the 0.75- to 2.50-second range of driver perception reaction time to the FCWS warning. This table shows the possible outcomes using FCWS alone, without the added benefit of ACC or active braking.

Table 7. Scenario 1: FCWS for stationary Land Rover in traffic queue.[a]

Distance To Decelerate (feet)	Warning Time (seconds)	Driver’s Reaction Time (seconds)	Initial Speed of Truck (mph)	Impact Speed (mph)
308–350	3.00–3.40	2.50	70	**70–64**
308–350	3.00–3.40	1.50	70	**56–50**
308–350	3.00–3.40	0.75	70	**45–39**

[a]Land Rover is stationary in traffic queue; note that some currently available FCWSs cannot detect stationary objects or vehicles. Air brake lag time is 0.50 second.

The Volvo driver, although he was fatigued, was not incapacitated, and had he received an alert warning from an FCWS, he might have reacted with emergency braking. The accident truck could not have slowed down tremendously, given the assumption of a 2.50-second perception reaction time and the stopped traffic ahead. Under such circumstances, it can be estimated that the impact speed range would be 70 to 64 mph. If the FCWS alert had immediately redirected the driver’s attention to the traffic ahead, and the driver had reacted very quickly, faster reaction times of 1.50 and 0.75 second would have reduced the impact speed to a range of 56 to 39 mph. Although 56- and 39-mph impacts are significant, they are less severe than a 70-mph impact. In addition, at the lower speeds, the Volvo driver might even have been able to take evasive steering action to avoid or mitigate the accident. The driver could have attempted an evasive maneuver, such as steering to the right, onto the roadway’s paved

[202] Mobileye reported that its system would detect the vehicle at a distance of 3.00 seconds, which is 308 feet (using the estimated 70-mph speed of the truck). Bendix reported that its Wingman ACB and SmartCruise systems would detect and emit the collision imminent alert at 350 feet. Meritor WABCO reported that its system, OnGuard, does not currently detect stationary vehicles.

shoulder, or even off the road and onto the grassy right-hand right-of-way, to prevent striking the passenger vehicles.

Scenario 2—FCWS and Land Rover Moving Slowly. Had the Land Rover been moving slowly in traffic at 10 mph, the truck-tractor combination unit would have gained an additional 44 to 50 feet of distance over which to decelerate in this scenario, depending on the warning and perception reaction times used. The radar-based FCWSs would have detected the Land Rover at a range of 350 feet: one system would have emitted the audible alert at 350 feet, while another would have calculated the closing distance and sounded an audible alert at approximately 318 feet in closing distance. The camera-based system would have detected the slowly moving Land Rover at a following distance period of 3.00 seconds, which equates to 308 feet, and would have emitted an alert at this distance.

Table 8 shows that, had the traffic ahead been moving slowly, affording the Volvo truck a longer time and greater distance over which to decelerate, the impact speed of the truck could have been reduced to 38 mph under the most conservative reaction and warning time assumptions. Assuming a quicker driver reaction time of 1.50 seconds, the Volvo's impact speed could have been reduced to a range of between 24 and 14 mph. Given a driver reaction time of 0.75 second, the impact speed might have been reduced to as low as 9 mph, or the impact might even have been avoided.

Table 8. Scenario 2: FCWS for Land Rover moving 10 mph in traffic queue.[a]

Distance to Decelerate (feet)	Warning Time (seconds)	Driver's Reaction Time (seconds)	Initial Speed of Truck (mph)	Impact Speed (mph)
352–400	3.00–3.40	2.50	70	**38–31**
352–400	3.00–3.40	1.50	70	**24–14**
352–400	3.00–3.40	0.75	70	**9–0**

[a]Land Rover is moving at 10 mph; the systems detect the slower moving Land Rover at 350 feet and calculate the closing distance. Because the Land Rover is moving (constant slow speed of 10 mph), this increases the distance traveled progressively from the detection and collision calculation threshold even while the truck is moving faster, thus providing a slightly longer warning time to collision distance. Air brake lag time is 0.50 second.

One manufacturer indicated that with a bundled system on the Volvo truck, consisting of an FCWS with ACC and active braking, the driver could have brought the vehicle to a stop if he had applied 0.60 *g* emergency braking approximately 2.00 seconds after the active braking system engaged. In this scenario, the active braking itself might have alerted the driver to the impending hazard and caused him to initiate an appropriate response. According to the manufacturer, even if the driver had not initiated any emergency braking but the Volvo had been so equipped, this system might have been able to initiate CMB and slow the Volvo to an impact speed range of 48 to 53 mph without any driver action.

Scenario 3—FCWS With Bundled System and Land Rover Beginning to Decelerate From 75 mph When the FCWS Detects it at 70 mph. Both of the scenarios described above assume that the Volvo truck-tractor was 350 feet behind the Land Rover (or any other vehicle) when the FCWS detected it as stopped or slow-moving traffic. If, instead, both vehicles were traveling about 70 mph when the truck's FCWS detected the Land Rover—with at least 350 feet of separation distance—and the FCWS had been tracking the Land Rover when it began to slow in response to the traffic queue, this could have affected the accident outcome significantly.

In this case, if the Volvo truck had been equipped with an FCWS with ACC and active braking, the system would have automatically slowed the Volvo to a preset safe following distance (one manufacturer's default setting is 3.60 seconds) without driver input. Further, once the system detected that the vehicle ahead was continuing to slow, the Volvo with the FCWS, ACC, and active braking would have maintained the 3.60-second following distance by continuously slowing. When the Land Rover reached 0 mph, the Volvo truck-tractor semitrailer would also have slowed to 0 mph at a distance of 32 feet behind the Land Rover, thus entirely preventing the accident. The above "best case" scenario illustrates what might have been possible in the Miami accident with a vehicle equipped with an FCWS with active braking; under these very specific circumstances, such a system could have prevented an accident without any driver input.[203]

As discussed earlier, the Volvo's impact speed generated tremendous kinetic energy, which was dissipated when it collided with the slower moving passenger vehicles, causing them catastrophic damage. Kinetic energy is the mathematical expression of the truck's maximum ability to do damage.[204,205] Because kinetic energy is proportional to the square of the vehicle speed, the energy of the impacting vehicle and its ability to do damage decline quickly as speed is reduced. Table 9 below shows the amount of kinetic energy that the accident Volvo had at about 70 mph, when it struck the passenger vehicles, as well as the amount it would have had with the incremental reduction in speed provided either by an FCWS alone or by an FCWS with a bundled system, as described above. A reduction in speed from about 70 to 50 mph would have cut the kinetic energy of the impacting heavy commercial vehicle in half. Further reducing the impact speed to 39 mph would have caused an energy reduction of nearly 70 percent. The scenario of the FCWS system bundled with ACC and active braking, without any input from the driver, could have resulted in a reduction in speed from about 70 to 39 mph at impact. (See table 9.)

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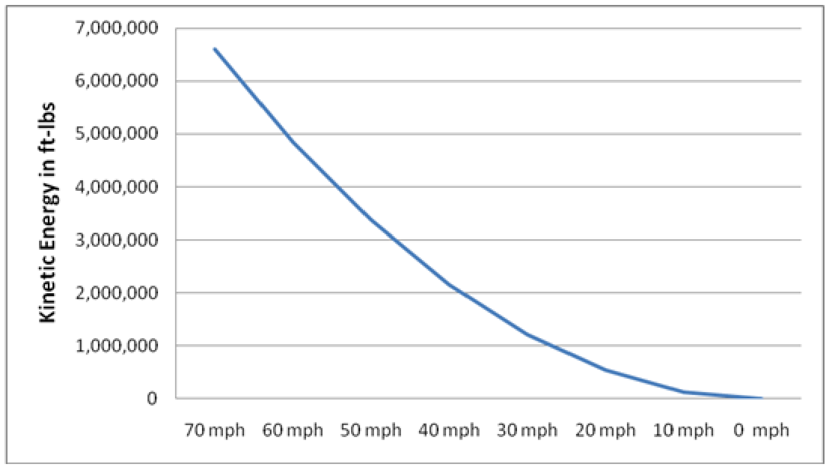
[203] Had the accident truck traveling about 70 mph detected and tracked the Land Rover traveling ahead at a similar speed, systems like the Wingman ACB and OnGuard could have slowed the truck-tractor at the same rate that the Land Rover slowed on approach to the stopped traffic, without any braking from the truck driver, given that the Land Rover did not initiate hard braking in excess of 0.30 to 0.35 *g*.

[204] Kinetic energy is defined as the energy of an object in motion and is equal to the work it would do if it were brought to rest. An object of mass (m) moving at velocity (v) has a kinetic energy equal to 1/2 mv^2.

[205] Not all of the kinetic energy of the truck was dissipated as vehicle damage. Kinetic energy was also dissipated as a result of friction forces between the ground and the truck and between vehicles.

Table 9. Scenario 3: Kinetic energy vs. speed.

Speed (mph)	Kinetic Energy (million ft-lbs)	Reduction in Kinetic Energy (%)
70	6.60	0.00
60	4.85	26.53
50	3.37	30.56
40	2.15	36.00
30	1.21	43.75
20	0.53	55.56
10	0.13	75.00
0	0.00	100.00



Depending on variables (such as the speed and distance of the vehicles ahead of the Volvo truck), even a bundled system might not have provided the fatigued Volvo driver sufficient time to react to the warning, brake the vehicle, and *prevent* the accident. However, it could have provided enough time for him to react, brake, and *mitigate* the severity of the accident or perhaps to *avoid* the collision through steering inputs.

It might not have been possible to bring the heavy Volvo truck-tractor semitrailer to a complete stop with FCWS and related technologies before any collision occurred. However, as can be seen in table 9, the slower the truck had been traveling at impact, the lower the kinetic energy involved in the accident and the less severe the damage to the struck passenger vehicles would have been. This scenario most likely would have resulted in less severe injuries to the occupants of those vehicles. In fact, if the Volvo truck-tractor had been equipped with an FCWS bundled with ACC and active braking, assuming that scenario 3 circumstances had existed in the seconds before the accident, it is possible that the system could have entirely prevented the accident. Therefore, the NTSB concludes that an FCWS with ACC and active braking would have provided the driver with the best opportunity to prevent, or reduce the severity of, the truck-tractor semitrailer's impact with the passenger vehicles in the traffic queue.

The NTSB considers that installing new technologies in CMVs—such as FCWSs, ACC, active braking, and ESC—has the potential to reduce accidents substantially. Following the investigation of an October 2005 accident in which five people were killed when a motorcoach collided with an overturned truck-tractor semitrailer combination unit on Interstate 94 near Osseo, Wisconsin,[206] the NTSB issued Safety Recommendation H-08-15 to NHTSA, asking the agency to take the following action:

[206] NTSB/HAR-08/02.

> 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)

Since February 26, 2010, Safety Recommendation H-08-15 has been "Open—Acceptable Response." Also in the Osseo report, the NTSB reiterated Safety Recommendations H-01-6 and -7 to NHTSA.

In a letter dated June 4, 2009, NHTSA responded to these NTSB recommendations by providing an update on its current projects evaluating the application of various technologies for commercial trucks and motorcoaches. NHTSA is conducting a test track evaluation of commercially available CMB systems and has indicated that an initial evaluation of their performance capabilities will be completed in 2010. A NHTSA project to evaluate the potential safety benefits of active braking systems is expected to be completed in 2011. Based on these reports of progress from NHTSA, Safety Recommendations H-01-6 and -7 were classified "Open—Acceptable Response."

Due to their high mileage exposure[207] and the severity of crashes involving them, combination-unit trucks have the highest crash cost per vehicle over the operational life of the vehicle; therefore, FCWSs may provide a relatively higher safety benefit for this class of trucks.[208] However, government and industry entities are still conducting operational testing and encouraging voluntary implementation of FCWSs. Although the work being done by private industry and the government is encouraging, the slow pace of testing and standards development and the limited deployment of FCWSs in commercial vehicles are cause for concern, given the large number of rear-end collisions and the high rate of fatalities that result when commercial vehicles are involved.

For years, the NTSB has been advocating the implementation of in-vehicle systems that enhance the safety of heavy vehicles, both by mitigating accident severity and preventing accidents altogether. Safety benefits are often not the result of one system on its own; more often, it is the synergy of systems working together that can prevent and mitigate a larger percentage of accidents, resulting in the greatest reduction of highway injuries and fatalities. Although FCWS use within a heavy vehicle is crucial to provide warning of an impending collision, integrating this safety system with related technologies would provide even greater opportunity for preventing accidents, as well as for reducing the severity and frequency of rear-end accidents. The NTSB considers that FCWSs have great promise and that the added feature of active braking increases their potential for preventing accidents. However, the pace of NHTSA's progress in this vital area has been too slow. Because NHTSA is still evaluating these systems and is not yet near rulemaking that would require them to be used in commercial vehicles, the NTSB reiterates Safety Recommendations H-01-6 and -7 and H-08-15. Further, although the NTSB acknowledges that NHTSA has made some progress in conducting research

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[207] Combination vehicles account for about 30 percent of all CMVs but about 65 percent of commercial vehicle miles traveled.

[208] See <http://www.fmcsa.dot.gov/facts-research/research-technology/report/forward-collision-warning-systems.htm> (accessed June 16, 2010).

in this area, due to the lack of timely completion of the recommended actions, Safety Recommendations H-01-6 and -7 are reclassified “Open—Unacceptable Response.” The status of Safety Recommendation H-08-15 remains “Open—Acceptable Response.”

Conclusions

Findings

1. The weather did not contribute to the accident.

2. The mechanical condition of the truck-tractor semitrailer combination unit was not a factor in this accident.

3. The accident truck driver was not under the influence of alcohol or any of the prescription, over-the-counter, and illicit drugs for which he was tested following the accident.

4. The emergency response from the Oklahoma Highway Patrol, the responding fire departments, the public and private emergency medical services ambulances, the medical helicopter services, and the wrecker service was timely, and the extrication of the injured was performed as expeditiously as possible.

5. No highway design or construction defects existed in the area of the accident site, and the available sight distance for the accident truck driver to observe the traffic queue and stop his vehicle exceeded the stopping sight distance recommended by the American Association of State Highway and Transportation Officials.

6. The cellular telephone activity in which the truck driver engaged while on duty failed to comply with Associated Wholesale Grocers, Inc., written policy.

7. Based on the available electronic control module data and analysis, the truck driver failed to apply the brakes at any time prior to, during, or after striking the slowed and stopped vehicles in the traffic queue and was operating the accident truck with the cruise control engaged at a speed of about 69 mph.

8. Based on the medical evidence and witness accounts concerning the accident truck driver's behavior and condition, it is unlikely that he experienced a medical event that might have caused or contributed to the accident.

9. The accident truck driver was impaired by fatigue at the time of the crash as a result of the effects of acute sleep loss, circadian disruption associated with his shift work schedule, and mild obstructive sleep apnea.

10. The truck driver's impairment from fatigue led to his failure to react to the slowing and stopped traffic ahead by applying brakes or performing any evasive maneuver to avoid colliding with the traffic queue.

11. The provision of new and updated information on sleep, fatigue, and alertness by the Federal Motor Carrier Safety Administration, based on contemporary scientific research, is essential to ensuring that commercial drivers have the necessary guidance to enable them to be alert and well rested when operating their vehicles.

12. Associated Wholesale Grocers, Inc., did not have a meaningful fatigue management program in place at the time of the accident.

13. The use of fatigue management programs by motor carriers has the potential to reduce accidents caused by fatigued commercial drivers.

14. The combination of the high impact speed of the Volvo truck-tractor semitrailer and the structural incompatibility between the Volvo and the passenger vehicles resulted in extensive intrusion deformation and crush damage to the passenger compartments of the Land Rover, Hyundai, Kia, and Ford Windstar; a loss of survivable space in those vehicles; and the deaths of 10 passenger vehicle occupants.

15. Even though heavy truck incompatibility is a major cause of death for occupants of passenger cars, light trucks, and vans involved in crashes with heavy trucks, to date, the U.S. Department of Transportation and the National Highway Traffic Safety Administration have not made this issue a priority and have not allocated sufficient resources to study and address it.

16. The heavy truck in the Miami accident lacked a dedicated event data recorder designed for accident reconstruction and to provide accelerometer-based crash pulse data, which are critical to the evaluation of vehicle performance and could have been used in vehicle incompatibility research; therefore, these data are again unavailable to investigators and researchers.

17. Due to the lack of government standards and requirements for the design and use of highway vehicle event data recorders, valuable high-fidelity crash data continue to go unrecorded and, thus, are unavailable for analysis.

18. Video event recorders have the potential to increase safe behavior among commercial drivers through structured safety performance monitoring, which may lead to decreases in accidents and injuries.

19. Had the accident truck been equipped with a video event recorder, a more definitive assessment of the driver's precrash condition and behavior would have been possible.

20. A forward collision warning system with adaptive cruise control and active braking would have provided the driver with the best opportunity to prevent, or reduce the severity of, the truck-tractor semitrailer's impact with the passenger vehicles in the traffic queue.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the Volvo truck driver's fatigue, caused by the combined effects of acute sleep loss, circadian disruption associated with his shift work schedule, and mild sleep apnea, which resulted in the driver's failure to react to slowing and stopped traffic ahead by applying the brakes or performing any evasive maneuver to avoid colliding with the traffic queue. Contributing to the severity of the accident were the Volvo truck-tractor combination unit's high impact speed and its structural incompatibility with the passenger vehicles.

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:

> Create educational materials that provide current information on fatigue and fatigue countermeasures and make the materials available in different formats, including updating and redistributing your truck-driver-focused driver fatigue video; make the video available electronically for quicker dissemination; and implement a plan to regularly update the educational materials and the video with the latest scientific information and to regularly redistribute them. (H-10-8)

> Require all motor carriers to adopt a fatigue management program based on the North American Fatigue Management Program guidelines for the management of fatigue in a motor carrier operating environment. (H-10-9)

> Require all heavy commercial vehicles to be equipped with video event recorders that capture data in connection with the driver and the outside environment and roadway in the event of a crash or sudden deceleration event. The device should create recordings that are easily accessible for review when conducting efficiency testing and systemwide performance-monitoring programs. (H-10-10)

> Require motor carriers to review and use video event recorder information in conjunction with other performance data to verify that driver actions are in accordance with company and regulatory rules and procedures essential to safety. (H-10-11)

To the National Highway Traffic Safety Administration:

> To improve highway vehicle crash compatibility, develop performance standards for front underride protection systems for trucks with gross vehicle weight ratings over 10,000 pounds. (H-10-12) (This recommendation supersedes Safety Recommendation H-06-16 and is classified "Open—Unacceptable Response.")

> After establishing performance standards for front underride protection systems for trucks with gross vehicle weight ratings over 10,000 pounds, require that all such newly manufactured trucks be equipped with front underride protection systems meeting the performance standards. (H-10-13)

Develop and implement minimum performance standards for event data recorders for trucks with gross vehicle weight ratings over 10,000 pounds that address, at a minimum, the following elements: data parameters to be recorded; data sampling rates; duration of recorded event; standardized or universal data imaging interface; data storage format; and device and data survivability for crush, impact, fluid exposure and immersion, and thermal exposure. The standards should also require that the event data recorder be capable of capturing and preserving data in the case of a power interruption or loss, and of accommodating future requirements and technological advances, such as flashable and/or reprogrammable operating system software and/or firmware updates. (H-10-14)

After establishing performance standards for event data recorders for trucks with gross vehicle weight ratings over 10,000 pounds, require that all such vehicles be equipped with event data recorders meeting the standards. (H-10-15)

To Associated Wholesale Grocers, Inc.:

Create and implement a comprehensive fatigue management program using existing sources of information, and develop a systematic process to update the program as more guidance becomes available. (H-10-16)

Previously Issued Recommendations Reiterated and Reclassified in This Report

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

To the U.S. Department of Energy:

Report to the National Transportation Safety Board the 21st Century Truck Partnership's plans and timetable for prioritizing research, testing, and design enhancements that address heavy truck aggressivity. (H-06-15)

Safety Recommendation H-06-15 is reclassified "Open—Unacceptable Response" in the "Vehicle Occupant Survival, Heavy Vehicle Aggressivity" Analysis section of this report.

To the National Highway Traffic Safety Administration:

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-01-6)

Safety Recommendation H-01-6 is reclassified "Open—Unacceptable Response" in the "Forward Collision Warning Systems" Analysis section of this report.

> After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system. (H-01-7)

Safety Recommendation H-01-7 is reclassified "Open—Unacceptable Response" in the "Forward Collision Warning Systems" Analysis section of this report.

Previously Issued Recommendations Reiterated in This Report

As a result of its investigation, the National Transportation Safety Board reiterates 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)

Previously Issued Recommendation Reclassified in This Report

As a result of its investigation, the National Transportation Safety Board reclassifies the following safety recommendation:

To the National Highway Traffic Safety Administration:

> Include heavy vehicles in your research, testing, and eventual rulemaking on highway vehicle incompatibility, especially as that incompatibility affects the severity of accidents. (H-06-16)

Safety Recommendation H-06-16 is reclassified "Closed—Unacceptable Action/Superseded" (superseded by Safety Recommendation H-10-12) in the "Vehicle Occupant Survival, Heavy Vehicle Aggressivity" Analysis section of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: September 28, 2010

Appendix A: Investigation

The National Transportation Safety Board was notified of the Miami, Oklahoma, accident on June 26, 2009. An investigative team composed of members from the Washington, D.C.; Gardena, California; and Arlington, Texas, offices was dispatched on June 29. Groups were established to investigate human performance factors; motor carrier operations; and highway, vehicle, and survival factors. No Board Member traveled to the accident scene.

Parties to the investigation were the Federal Motor Carrier Safety Administration and the Oklahoma Turnpike Authority. The motor carrier Associated Wholesale Grocers, Inc., declined party status.

No public hearing was held; no depositions were taken.

Appendix B: Photographs of Vehicles Struck in Fatal Accident

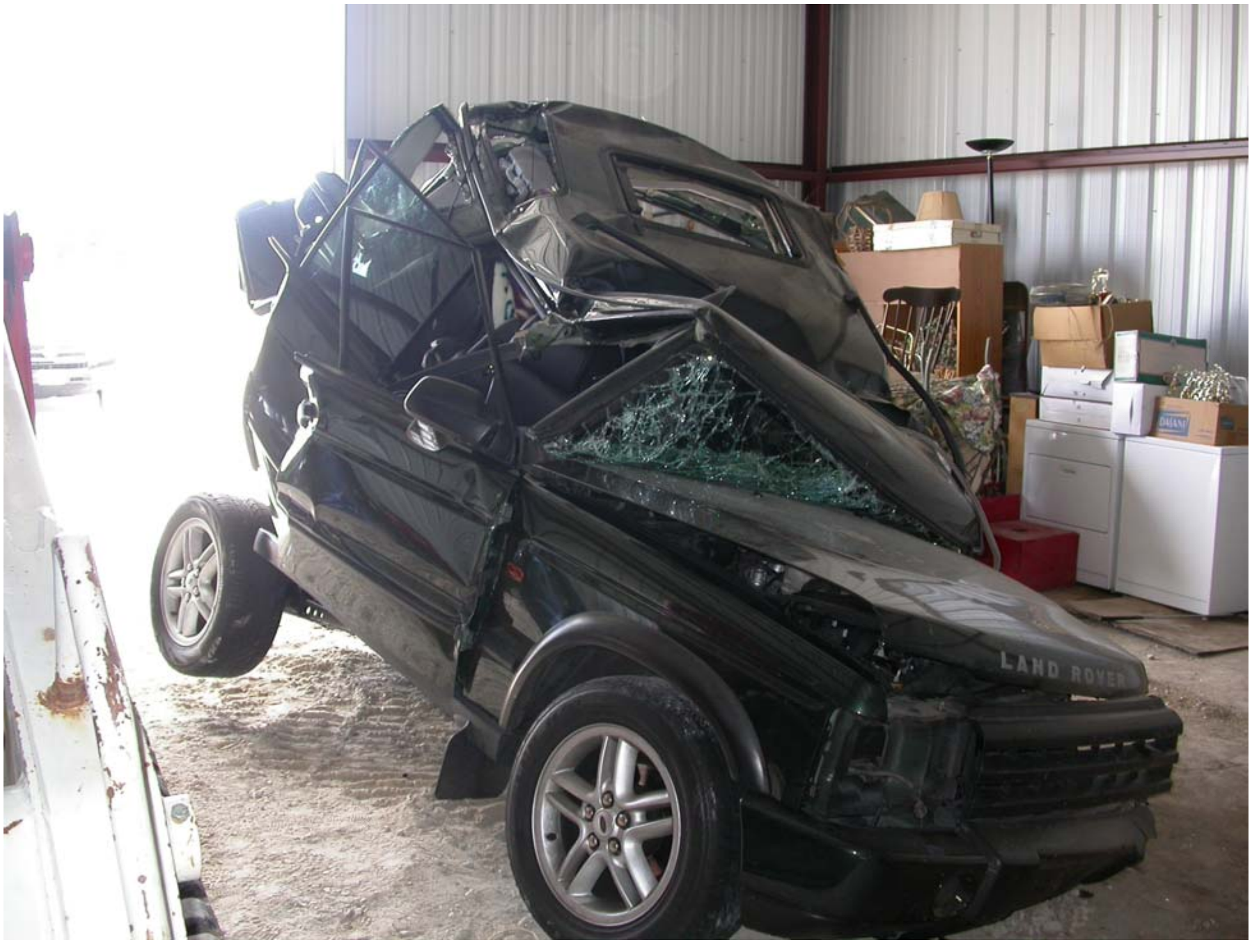

Figure B-1. Collision damage to 2003 Land Rover SUV.

Figure B-2. Collision damage to 2003 Hyundai Sonata sedan.

Figure B-3. Collision damage to 2004 Kia Spectra sedan.

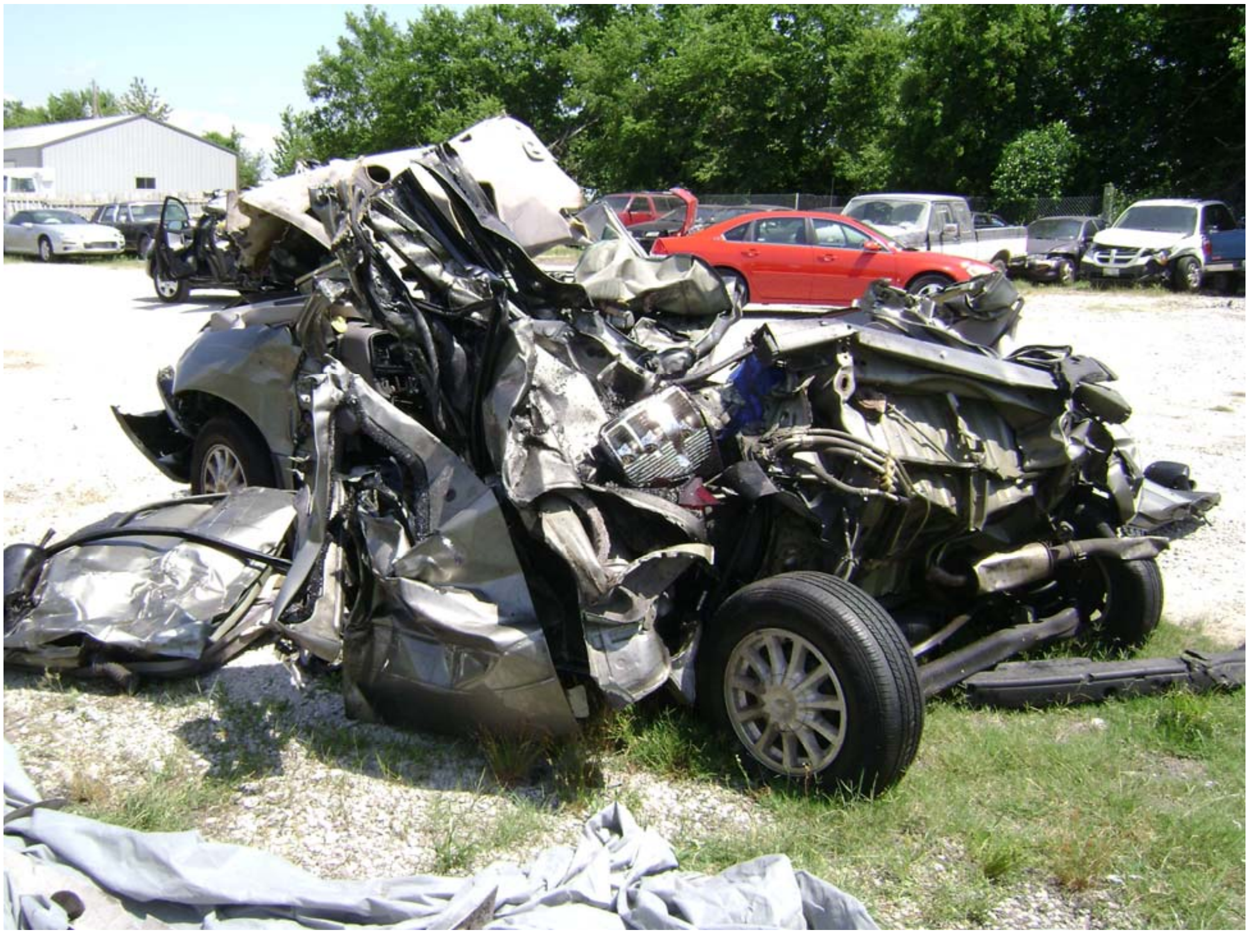

Figure B-4. Collision damage to 2000 Ford Windstar minivan.

Figure B-5. Collision damage to livestock trailer pulled by Ford F350 pickup truck.

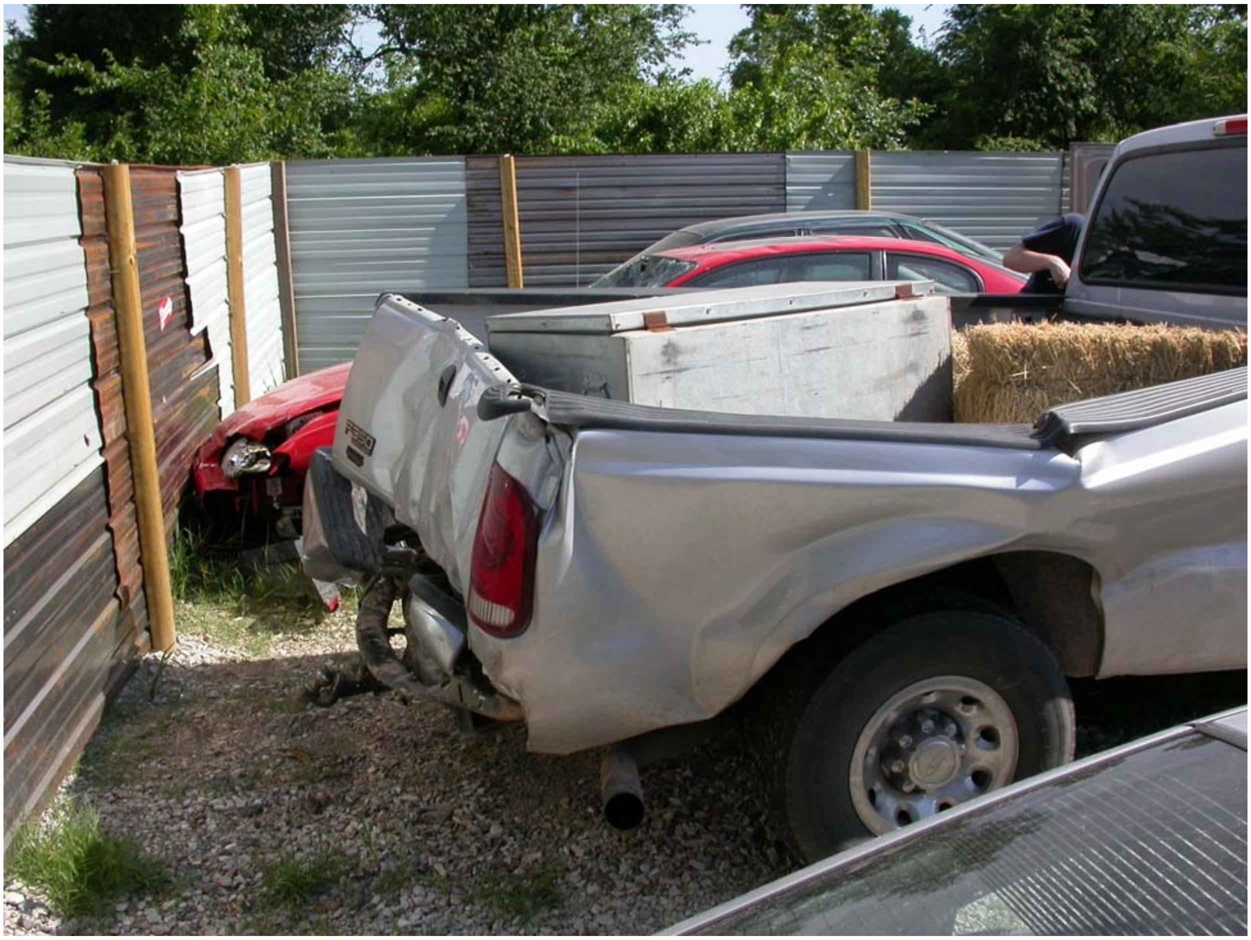

Figure B-6. Collision damage to 2004 Ford F350 pickup truck.

Figure B-7. Collision damage to 2008 Chevrolet Tahoe SUV.

Appendix C: Associated Wholesale Grocers, Inc., Mobius On-Board Computer System

Company drivers log onto the Cadec Mobius TTS on-board computer (OBC) system at the beginning of their shifts with a unique identifying number. A monitoring device and screen are mounted next to the driver in the cab of the truck-tractor. The results are transmitted in real time to the carrier and are put in a logbook format (off-duty; sleeper berth; on-duty, driving; and on-duty, not driving). The unit is capable of monitoring the 11-, 14-, and 70-hour rules. The Mobius OBC system is available with numerous optional features to suit the specific needs of the end user.

Whenever the driver reaches 1 hour from either the 11-hour driving or 14-hour on-duty limit, an alarm sounds in the cab's unit. The driver must acknowledge the alarm by touching the computer screen on the unit and then must decide whether to continue to the destination, stop and rest, or stop and request a relief driver. Violations of the hours-of-service (HOS) regulations cause a notification on the Mobius OBC printout. An Associated Wholesale Grocers administrative assistant reviews the logbook entries and notifies a supervisor of the violation. The driver is consulted and discipline occurs within the criteria of the union contract.

Valuable data were recovered from the accident vehicle's Mobius OBC system. The computerized in-cab driver interface is used to electronically record U.S. Department of Transportation (DOT) HOS logs, and the system incorporates a global positioning system (GPS). The 12-channel GPS receiver could be used to produce detailed records, including driver-reported accident events, sudden decelerations, unknown stops, and complete trip recordings.

The Mobius OBC is designed and marketed as a fleet management system, providing companies with data analysis and reporting capabilities to optimize mobile resources, improve driver performance, and provide DOT HOS compliance. The unit is capable of monitoring the vehicle and engine speed thresholds.

The Mobius OBC is also a wireless communications device between the company and the driver. The company can send a message to the driver that causes an alert to sound in the vehicle cab. The driver may acknowledge the alert by touching the in-cab computer screen but must stop the vehicle to read or respond to messages.

Appendix D: Postaccident Compliance Review of Associated Wholesale Grocers, Inc.

Table D-1. Violations found in postaccident (July 15, 2009) Federal Motor Carrier Safety Administration (FMCSA) compliance review of Associated Wholesale Grocers, Inc.

ACUTE AND CRITICAL VIOLATIONS[a]	
Code of Federal Regulations **(CFR) Reference**	**Deficiency Noted**
382.215—Acute	Using a driver known to have tested positive for a controlled substance.
392.301—Critical	Using a driver before the motor carrier has received a negative preemployment controlled substance test result.
OTHER VIOLATIONS	
CFR Reference	**Deficiency Noted**
40.11(a) (Primary) **382.105 (Secondary)**	Failing to ensure that controlled substance testing complies with the procedures set forth in 49 CFR Part 40.
40.47(a) (Primary) **382.105 (Secondary)**	Using a U.S. Department of Transportation (DOT) custody control form to perform a non-DOT test.
382.401(c)(6)	Failing to maintain semiannual laboratory statistical summaries of urinalysis required by 49 CFR 40.29(g)(6).
390.15(b)(1)	Failing to keep an accident register in the form and manner prescribed.
391.25(a)	Failing to make an inquiry into the driving record of each driver to the appropriate agencies in the state in which the driver held a commercial motor vehicle operator's license at least once every 12 months.
395.8(f)	Failing to require a driver to prepare a record-of-duty status in the form and manner prescribed.
396.9(d)(3)	Failing to maintain a completed inspection form for 12 months from the date of inspection at the carrier's principal place of business.

[a]Recurring violations of the same or related acute or critical regulations that result in three enforcement actions within a 6-year period will trigger the maximum penalties allowed by law to be assessed for the third enforcement action.

According to SafeStat,[1] from September 27, 2007, through May 20, 2009, Associated Wholesale Grocers, Inc. (AWG), had 100 driver inspections, resulting in no out-of-service (OOS) violations. From December 27, 2006, through May 20, 2009, the carrier had 92 vehicle inspections, resulting in 22 OOS violations (the accident vehicle was not one of those inspected). AWG drivers were issued 25 moving violations from December 27, 2006, through May 5, 2009; one was for an improper lane change, one was for failure to obey a traffic control device, and the rest were for speeding.

As of July 12, 2010, AWG's safety rating was satisfactory.

[1] "SafeStat" (the Motor Carrier Safety Status Measurement System) is an automated data-driven analysis system that combines current and historical carrier-based safety performance information to measure the relative (peer-to-peer) safety fitness of interstate commercial motor carriers (and intrastate commercial motor carriers that transport hazardous materials). This information includes Federal and state data on crashes, roadside inspections, on-site compliance review results, and enforcement history. SafeStat enables the Federal Motor Carrier Safety Administration to quantify and monitor the safety status of individual carriers on a monthly basis and thereby focus enforcement resources on carriers posing the greatest safety risk. In brief, SafeStat determines the current relative safety status of individual motor carriers.