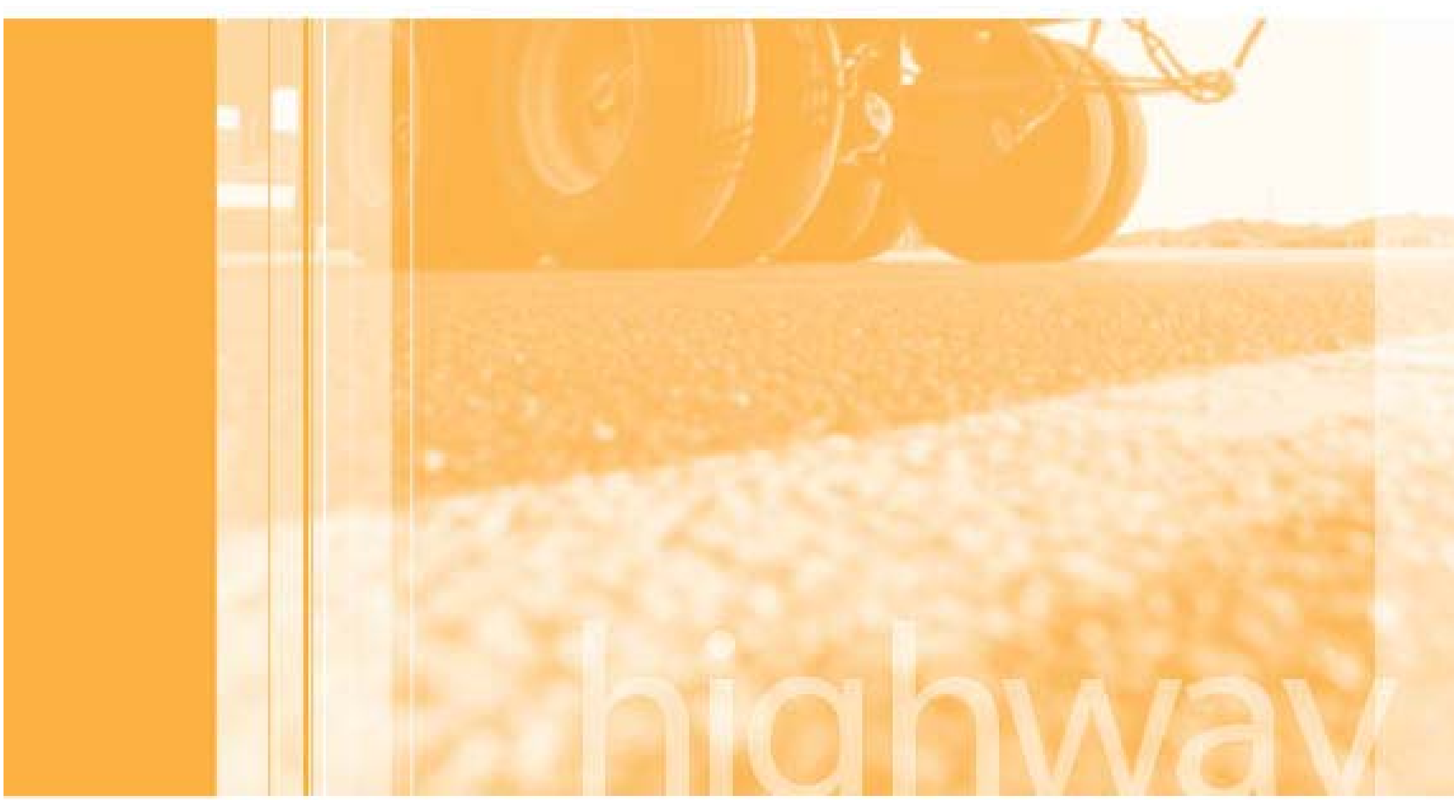
Motorcoach Run-Off-the-Road and Rollover
U.S. Route 163
Mexican Hat, Utah
January 6, 2008



Accident Report

NTSB/HAR-09/01
PB2009-916201

National
Transportation
Safety Board

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NTSB/HAR-09/01
PB2009-916201
Notation 8024A
Adopted April 21, 2009

Highway Accident Report

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January 6, 2008

National Transportation Safety Board

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

National Transportation Safety Board. 2009. ***Motorcoach Run-Off-the-Road and Rollover, U.S. Route 163, Mexican Hat, Utah, January 6, 2008*****. Highway Accident Report NTSB/HAR-09/01. Washington, DC.**

Abstract: About 8:02 p.m., mountain standard time, a 2007 Motor Coach Industries 56-passenger motorcoach with a driver and 52 passengers on board was traveling southbound, descending a 5.6-percent grade leading to a curve to the left, 1,800 feet north of milepost 29 on U.S. Route 163. After entering the curve, the motorcoach departed the right side of the roadway at a shallow angle, striking the guardrail with the right-rear wheel and lower coach body. The motorcoach traveled approximately 350 feet along the foreslope, with the right tires off the roadway. The back tires lost traction as the foreslope transitioned into the drainage ditch. The motorcoach rotated in a counterclockwise direction as it descended an embankment. The motorcoach overturned, struck several rocks in a drainage ditch bed at the bottom of the embankment, and came to rest on its wheels. During the 360-degree rollover sequence, the roof of the motorcoach separated from the body, and 50 of the 53 occupants were ejected. Nine passengers were fatally injured, and 43 passengers and the driver received injuries ranging from minor to serious.

Major safety issues identified by this accident investigation include driver fatigue, excessive vehicle speed, hours-of-service violations, motor carrier trip planning, motorcoach occupant protection, and emergency medical notification and response with regard to large motorcoaches traveling on rural roads. As a result of its investigation, the Safety Board makes recommendations to the Federal Interagency Committee on Emergency Medical Services, the Utah Bureau of Emergency Medical Services, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, the National Association of State Emergency Medical Services Officials, the American Bus Association, the United Motorcoach Association, and Arrow Stage Lines. The Safety Board also reiterates one previously issued recommendation to the Federal Motor Carrier Safety Administration.

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Acronyms and Abbreviations

ABA	American Bus Association
ADT	average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ALS	advanced life support
BLS	basic life support
BMI	body mass index
CDL	commercial driver's license
CPAP	continuous positive airway pressure
CFR	*Code of Federal Regulations*
CSRS	continuous shoulder rumble strips
E-911	Enhanced 911
ECE	Economic Commission for Europe
ECM	electronic control module
EMS	emergency medical service
EMT	emergency medical technician
EOBR	electronic on-board recorder
FARS	Fatality Analysis Reporting System
FEMA	Federal Emergency Management Agency

FHWA	Federal Highway Administration
FICEMS	Federal Interagency Committee on Emergency Medical Services
FMCSA	Federal Motor Carrier Safety Administration
FMCSRs	*Federal Motor Carrier Safety Regulation*s
FMVSS	Federal Motor Vehicle Safety Standard
GAO	U.S. Government Accountability Office
GPS	global positioning system
GUI	graphical user interface
GVWR	gross vehicle weight rating
HSIP	Highway Safety Improvement Program
IFR	instrument flight rules
IP	Internet protocol
ISS	inspection selection system
MCI	Motor Coach Industries
MCMIS	Motor Carrier Management Information System
MRB	Medical Review Board
MUTCD	*Manual on Uniform Traffic Control Devices*
NHTSA	National Highway Traffic Safety Administration
NIMS	National Incident Management System

NPRM	notice of proposed rulemaking
NTIA	National Telecommunications and Information Administration
PIEV	perception-identification-emotion-volition
PRT	perception-reaction time
PSAP	public safety answering points
SafeStat	Motor Carrier Safety Status Measurement System
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SCT	specialty care transport
UDOT	Utah Department of Transportation
UMA	United Motorcoach Association
U.S.C.	*United States Code*
U.S. 163/191	U.S. Route 163/191
VEDR	video event data recorder
VMT	vehicle miles traveled

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Executive Summary

On January 6, 2008, about 3:15 p.m. mountain standard time, a 2007 Motor Coach Industries 56-passenger motorcoach with a driver and 52 passengers on board departed Telluride, Colorado, en route to Phoenix, Arizona, as part of a 17-motorcoach charter. The motorcoach passengers were returning from a 3-day ski trip. The normal route from Telluride to Phoenix along Colorado State Route 145 was closed due to snow, and the lead driver planned an alternate route that included U.S. Route 163/191 through Utah.

About 8:02 p.m., the motorcoach was traveling southbound, descending a 5.6-percent grade leading to a curve to the left, 1,800 feet north of milepost 29 on U.S. Route 163. The weather was cloudy, and the roadway was dry at the time of the accident. After entering the curve, the motorcoach departed the right side of the roadway at a shallow angle, striking the guardrail with the right-rear wheel and lower coach body about 61 feet before the end of the guardrail. The motorcoach traveled approximately 350 feet along the foreslope (portion of roadside sloping away from the roadway), with the right tires off the roadway. The back tires lost traction as the foreslope transitioned into the drainage ditch.

The motorcoach rotated in a counterclockwise direction as it descended an embankment. The motorcoach overturned, struck several rocks in a drainage ditch bed at the bottom of the embankment, and came to rest on its wheels. During the 360-degree rollover sequence, the roof of the motorcoach separated from the body, and 50 of the 53 occupants were ejected. As a result of this accident, 9 passengers were fatally injured, and 43 passengers and the driver received injuries ranging from minor to serious.

The National Transportation Safety Board determines that the probable cause of this accident was the driver's diminished alertness due to inadequate sleep resulting from a combination of head congestion, problems acclimating to high altitude, and his sporadic use of his continuous positive airway pressure sleeping device during the accident trip. The driver's state of fatigue affected his awareness of his vehicle's excessive speed and lane position on a downhill mountain grade of a rural secondary road. Contributing to the accident's severity was the lack of an adequate motorcoach occupant protection system, primarily due to the National Highway Traffic Safety Administration's delay in developing and promulgating standards to enhance the protection of motorcoach passengers.

Major safety issues identified by this accident investigation include driver fatigue, excessive vehicle speed, hours-of-service violations, motor carrier trip planning, motorcoach occupant protection, and emergency medical notification and response with regard to large motorcoaches traveling on rural roads. As a result of its investigation, the Safety Board makes recommendations to the Federal Interagency Committee on Emergency Medical Services, the Utah Bureau of Emergency Medical Services, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, the National Association of State Emergency Medical Services Officials, the American Bus Association, the United

Motorcoach Association, and Arrow Stage Lines. The Safety Board also reiterates one previously issued recommendation to the Federal Motor Carrier Safety Administration.

Factual Information

On January 6, 2008, about 3:15 p.m. mountain standard time,[1] a 2007 Motor Coach Industries (MCI) 56-passenger motorcoach with a driver and 52 passengers on board departed Telluride, Colorado, en route to Phoenix, Arizona, as part of a 17-motorcoach charter.[2] The motorcoach passengers were returning from a 3-day ski trip. The normal route from Telluride to Phoenix along Colorado State Route 145 was closed due to snow,[3] and the lead driver planned an alternate route that included U.S. Route 163/191 (U.S. 163/191) through Utah.

About 8:02 p.m., the motorcoach was traveling southbound, descending a 5.6-percent grade leading to a curve to the left, 1,800 feet north of milepost 29 on U.S. 163. The weather was cloudy and the roadway was dry at the time of the accident. After entering the curve, the motorcoach departed the right side of the roadway at a shallow angle, striking the guardrail with the right-rear wheel and lower coach body about 61 feet before the end of the guardrail. The motorcoach traveled approximately 350 feet along the foreslope (portion of roadside sloping away from roadway), with the right tires off the roadway. The back tires lost traction as the foreslope transitioned into the drainage ditch.

The motorcoach rotated in a counterclockwise direction as it descended an embankment. The motorcoach overturned, struck several rocks in a drainage ditch bed at the bottom of the embankment, and came to rest on its wheels. During the 360-degree rollover sequence, the roof of the motorcoach separated from the body, and 50 of the 53 occupants were ejected. As a result of this accident, 9 passengers were fatally injured, and 43 passengers and the driver received injuries ranging from minor to serious.

Events Preceding the Accident

Arrow Stage Lines provided 17 motorcoaches for the charter trip from Phoenix, Arizona, to Telluride, Colorado, returning to Phoenix. According to the accident driver's trip log, he arrived at the designated pickup location at a Phoenix shopping center about 7:35 a.m. on Thursday, January 3, 2008, for the weekend ski trip. After loading passengers, he departed about 9:15 a.m. and completed the 486-mile trip to Telluride, arriving about 5:30 p.m. During Friday and Saturday of the Telluride layover, the driver was off duty, though records show he purchased fuel for the motorcoach midday on Friday, January 4.

The driver had obstructive sleep apnea, which was being treated with a continuous positive airway pressure (CPAP) device. While in Telluride, the driver had symptoms of a head

[1] Unless otherwise indicated, all times given in this report are mountain standard time.

[2] Although the 17 motorcoaches were en route to the same destination, they did not travel as a group.

[3] The closure occurred at Lizard Head Pass.

cold and self-medicated using an over-the-counter, nondrowsy cold medicine. His head congestion prevented effective use of the CPAP device. The driver told another driver that he slept poorly and had symptoms of a head cold. He told Safety Board investigators that he was not able to use the device effectively during his stay in Telluride due to his congestion and that he slept poorly.

On Sunday, January 6, 2008, the driver awoke at 6:45 a.m. and attended a driver's meeting at 10:00 a.m., at which he was informed by the lead driver that a portion of the return route was closed due to snow. A different return route to Phoenix was established. The alternate route was 70 miles longer than the originally planned route. He installed tire chains on the motorcoach, loaded passengers at 2:00 p.m., and departed Telluride at 3:15 p.m. The return trip, as planned, was 556 miles in snowy weather.

Accident Narrative

The motorcoach's travel route was affected by snow and ice during the Colorado segment of the trip. After crossing into Utah, the accident motorcoach turned south on U.S. 163/191 for approximately 80 miles, at which point U.S. 191 separates with a left turn to the south before crossing into Arizona. The accident driver missed the turn to remain on U.S. 191; instead he stayed on U.S. 163 going further west. Both U.S. 163 and U.S. 191 eventually join U.S. 160 heading southwest through Arizona. Most of the caravan of motorcoaches took the U.S. 191 route; the accident driver and one other driver remained on U.S. 163. Figure 1 shows the route of the motorcoach in the vicinity of the accident. In a postaccident interview, the driver stated that he was unsure of which route he was traveling but knew that the route he was on would take him toward Phoenix.

After several miles of downhill road and just before milepost 29, U.S. 163 begins a gradual, long curve to the left. Shortly after entering that curve, the bus departed the right side of the roadway at a shallow angle. There were no skid marks on the highway, and no other vehicles were involved in the run-off-the-road event. Evidence of tire marks was found along the guardrail for 61 feet before the guardrail came to an end.[4] Two sets of tire marks on the side slope showed the front tires were tracking nearer the top of the embankment, and furrows from the rear tires were found further down the embankment. Tire marks are shown in figures 2 and 3.

[4] The motorcoach's force against the guardrail did not deform the W-beam rail nor did it break any weak-beam support posts.

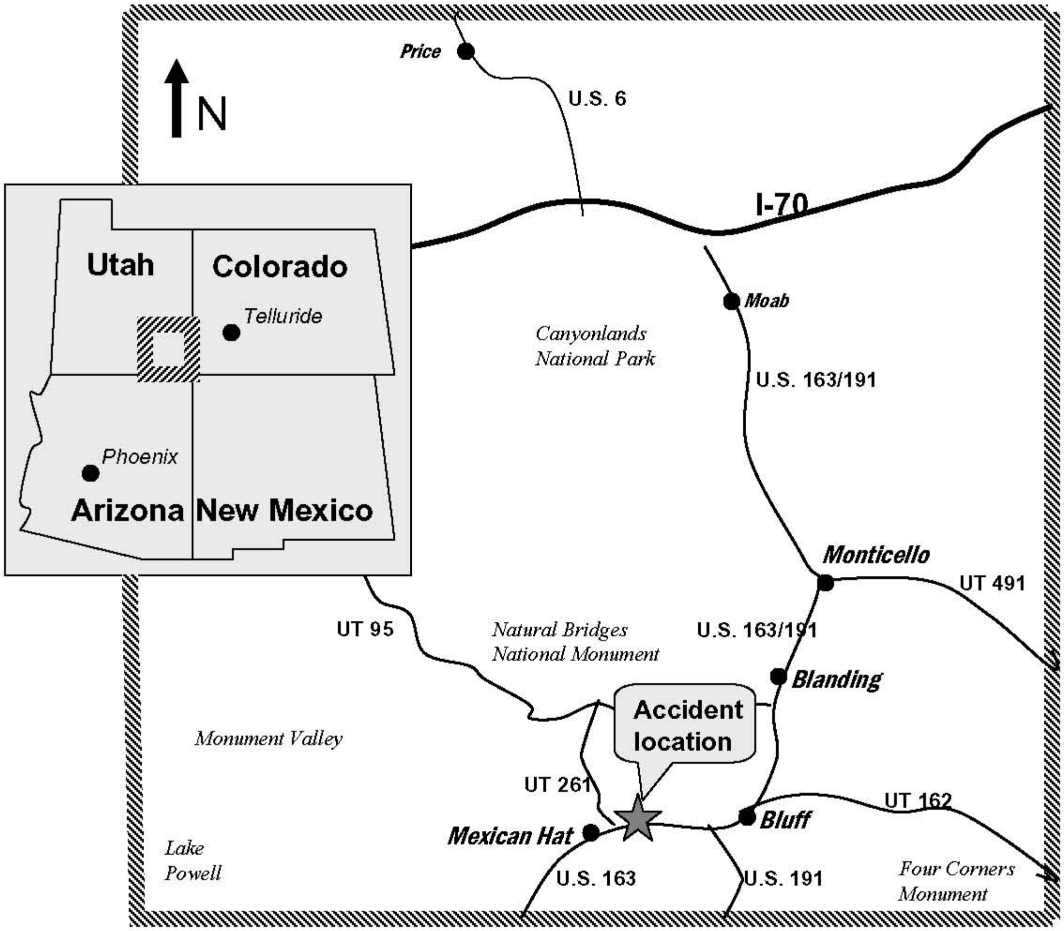

Figure 1. Accident motorcoach's route.

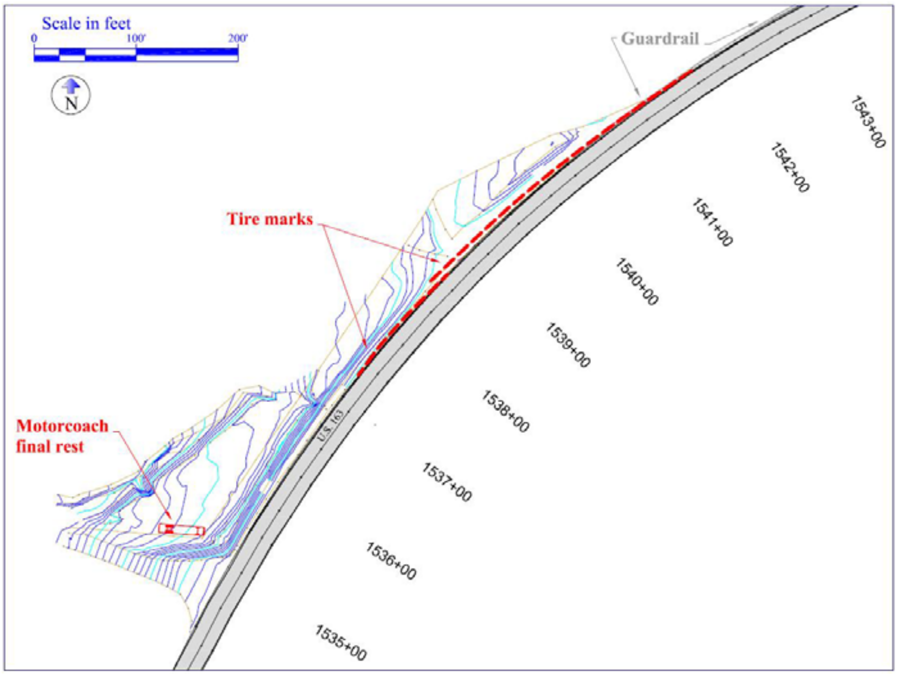

Figure 2. Scene diagram showing tire marks (dashed plow marks show the tire tracks gradually departing the road).

Figure 3. Tire marks on roadway (row of traffic cones to left of roadway follow the tire marks onto the foreslope).

After departing the roadway, the motorcoach traveled approximately 350 feet before the rear wheels went off the embankment.[5] The rear of the motorcoach rotated counterclockwise, with the front of the motorcoach facing perpendicular to the roadway.[6] The motorcoach overturned, rolling to the right, and struck a rocky drainage ditch at the bottom of the embankment approximately 10 feet lower than the roadway. During the rollover sequence, the roof separated from the bus body at the point where the vertical posts attached to the base of the window sash along the right side and, subsequently, the roof separated from the motorcoach. During the accident sequence, the motorcoach impacted the ground and completed a full rotation (360 degrees) before coming to rest on its wheels. Figures 4 and 5 show the accident motorcoach in its final location after the accident.

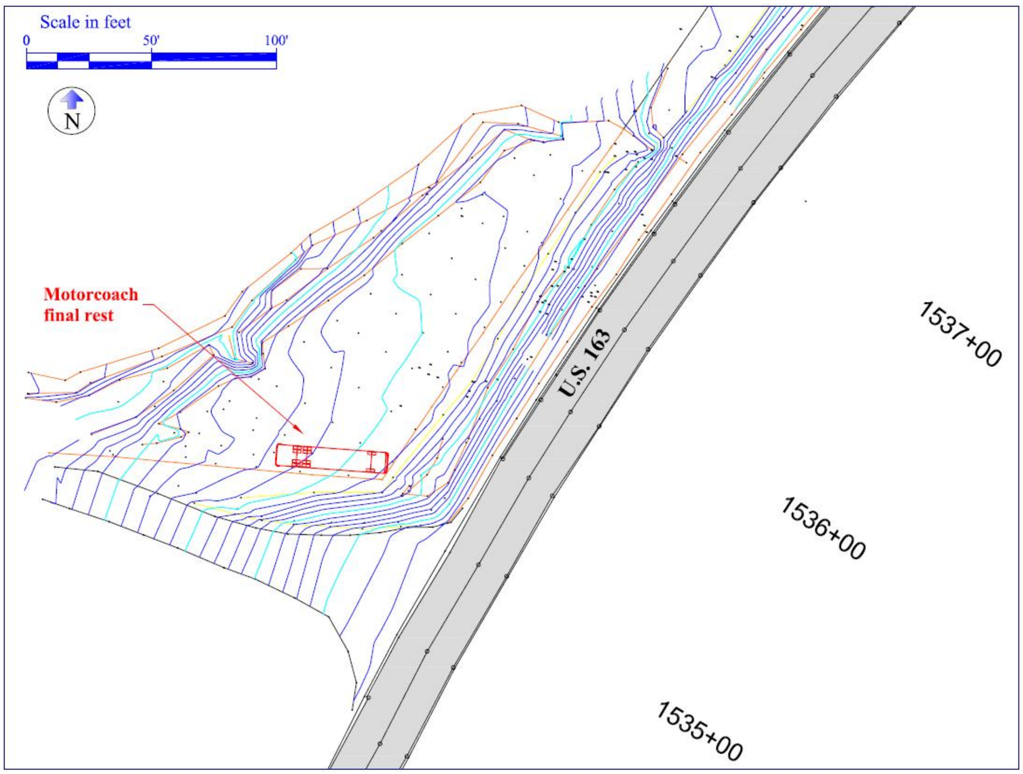

Figure 4. Position of accident motorcoach at end of rollover sequence (topographical contour lines indicate steepness of the embankment or slope; the closer the lines, the steeper the slope).

5 Survey information in figure 2 shows the plow marks of the tires departing the pavement at station number 154,200 and ending at approximately station number 153,850, a difference of 350 feet.

6 One ground scar near the roadside showed that the front of the vehicle impacted the ground at 37 degrees relative to the roadside.

Figure 5. Accident motorcoach's final location, as viewed looking back toward the route traveled. (U.S. 163 is behind the motorcoach, with the curve coming around the bluff in the center of the horizon.)

Injuries

In this accident, 50 of 53 motorcoach occupants were ejected from the vehicle. The driver, who was wearing a three-point restraint, and one passenger, who was entrapped between damaged seats in rows 12 and 13,[7] remained in the motorcoach. Another passenger told investigators that he was able to remain in his seat and exited after the motorcoach came to rest. The 9 fatally injured passengers died of blunt-force trauma to their heads and torsos; 13 of the 35 seriously injured occupants sustained a combination of fractures to the spine, torso, and extremities; and 12 of the remaining 22 seriously injured occupants sustained head and internal chest injuries. (See table 1 for a summary of injuries.) Passengers sustaining minor injuries had lacerations that required sutures, along with multiple abrasions and contusions to their faces, torsos, or extremities.

[7] The passenger trapped between rows 12 and 13 had been seated in row 9.

Table 1. Injuries.

Injury type	Drivers	Passengers	Total
Fatal	0	9	9
Serious	1	34	35
Minor	0	9	9
None	0	0	0
Total	1	52	53

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

During the accident sequence, the majority of passengers were ejected from the top of the motorcoach as the roof became separated from the right side at the base of the windows. Investigator interviews of surviving passengers revealed that at least two, and possibly as many as four, passengers were found on the right (east) side of the motorcoach at final rest. The majority of ejected passengers were found on the left (west) side of the motorcoach. According to first responders and passenger interviews, at least one person was found under the right (east) side of the motorcoach body and at least three people were fully or partially trapped underneath the roof of the motorcoach, which was detached to the left of the vehicle. Of those passengers, two survived.

Motorcoach passengers ranged in age from 5 to 67; the average age was 30. Fifteen passengers were 18 or younger; five fatalities were from this younger group. Seven passengers were pronounced dead at the scene of the accident and transported to two mortuaries. The average transport time between the accident scene and the initial critical care treatment facility was 2 hours 15 minutes. For ambulatory patients who were treated at the medical clinic in Blanding, Utah, the average transport time was 3 hours.

Two passengers died en route to critical care; both 16-year-old victims had sustained head and torso injuries from blunt-force trauma. After being transported to San Juan Hospital, Monticello, Utah, for stabilization, they were again transported to another medical hospital for a higher level of critical care. The time of death for one of the two en route victims was 3:36 a.m., 7 hours after the accident. That victim was in ground transport to Moab, Utah, to be airlifted to University Hospital in Salt Lake City. Due to the victim's deteriorating condition, the ambulance diverted to Allen Memorial Hospital in Moab, where the victim died. The second en route fatality occurred at 9:05 a.m., about 12.5 hours after the accident, as the accident victim arrived at St. Mary's Hospital in Grand Junction, Colorado.[8]

[8] Grand Junction is approximately 230 miles from the accident site by road and 115 miles by air.

As a result of the accident, 9 passengers sustained fatal injuries, 34 passengers and the driver sustained serious injuries, and 9 passengers received minor injuries. Figure 6 shows the seating locations and injury patterns of motorcoach occupants.

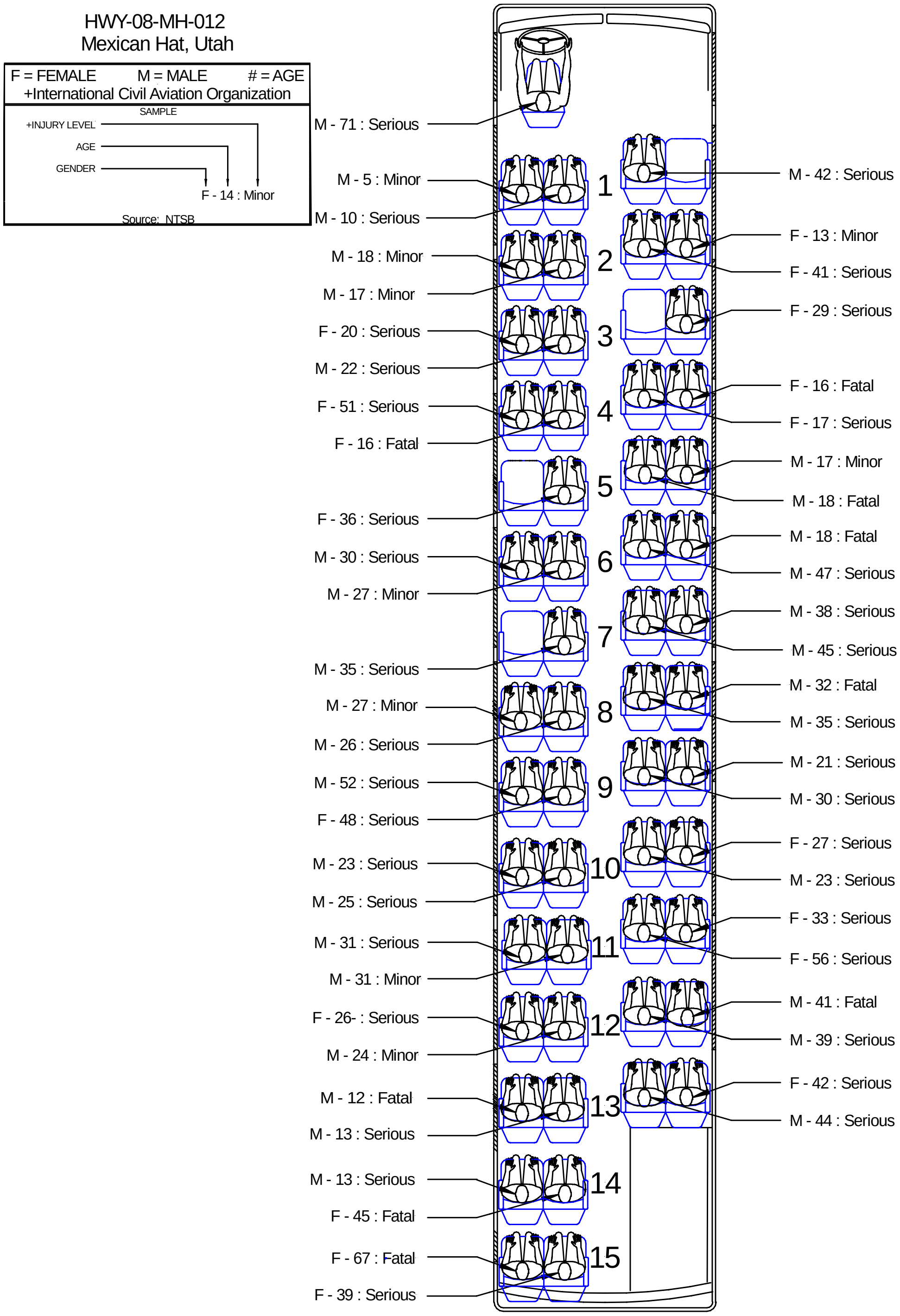

Figure 6. Seating diagram.

Of the 24 passengers who were seated on the right side of the motorcoach, 5 sustained fatal injuries (4 of 5 of these occupants were seated next to windows), 17 sustained serious injuries, and 2 sustained minor injuries. Of the 28 passengers who were seated on the left side of the motorcoach, 4 sustained fatal injuries (3 of 4 of these occupants were seated in the last three rows), 17 sustained serious injuries, and 7 sustained minor injuries.

Emergency Response

The San Juan County, Utah, Communication Center, located in the San Juan County Sheriff's Office, was notified of the accident through the 911 system at 8:38 p.m. The San Juan County 911 dispatcher received a call at 8:04 p.m. reporting a bus accident, but when the dispatcher asked for a location, the call was lost.[9] Following the accident, passengers alerted another motorist who passed the scene. That driver then drove to the next town, approximately 8 miles south, and called 911 from a service station.

The first call from dispatch went to the Utah Highway Patrol at 8:38 p.m. The Chief of the Bluff Volunteer Fire Department, who was the incident commander for this accident, said that after hearing radio traffic on his scanner, he departed for the scene at 8:33 p.m.[10] and arrived on scene at 8:56 p.m. The San Juan County Emergency Medical Service (EMS) Coordinator, who arrived at 9:56 p.m., was dispatched to the accident scene with the mass casualty incident trailer.[11] The Bluff Volunteer Fire Department rescue unit was en route at 8:45 p.m. and arrived on scene at 9:00 p.m., followed by its ambulance unit at 9:01 p.m. The first deputy with the San Juan County Sheriff's Office was dispatched at 8:48 p.m. and arrived on scene at 9:19 p.m. The Utah Highway Patrol sent four officers and the San Juan County Sheriff's Office sent four deputies to the scene.

Resources

San Juan County has eight ambulances, none of which are staffed for advanced life support (ALS) due to the county having no licensed paramedics, only certified intermediate or

[9] San Juan County does not have an Enhanced 911 system capable of automatically providing the public service answering point with identification and location information. The dispatcher had assumed that the dropped call was reporting a minor accident north of Blanding, Utah, which involved another of the other 16 motorcoaches on the ski trip. That accident occurred after the motorcoach became disabled on an ice-covered roadway 5 miles east of Blanding and another Arrow bus stopped to assist and was subsequently involved in a property damage accident when an automobile lost traction and slid into the stopped motorcoach.

[10] Times reported by the different response organizations—the San Juan County 911 dispatch, the Utah Highway Patrol, the Bluff Fire Department, and the San Juan County Sheriff's Office—were not synchronized and are therefore approximate.

[11] The mass casualty incident trailer is a mobile unit that can be towed to the accident site. It is supplied with backboards, neck braces, and other supplies needed to assist with emergency response during mass casualty events.

basic emergency medical technicians (EMTs).[12] All San Juan County EMTs are volunteers.[13] The following agencies responded to transport injured passengers:

- San Juan County EMS—eight ambulances, one transport ambulance, and three 15-passenger vans to transport the “walking wounded” to the Blanding medical clinic.
- Kayenta Navajo Nation—four basic life-support (BLS) ambulances.
- Moab–Grand County EMS—three ALS mutual aid ambulances.
- Mesa County, Colorado—two mutual aid ambulances.
- Southwest Memorial Hospital in Cortez, Colorado—two mutual aid ambulances from Durango, Colorado.

All of the on-scene ambulances traveled north from the accident site, except for the Navajo Nation ambulances, which traveled south. The less seriously injured were transported to the clinic in Blanding, 43 miles away; the more seriously injured were transported to San Juan Hospital, approximately 75 miles away, even though it had no trauma response capabilities. The injured were treated and released or triaged and transported to other medical facilities that had trauma units and could provide a higher level of care. According to the San Juan County EMS Coordinator on scene, the last ambulance transporting injured passengers left the accident site at approximately 12:20 a.m., more than 4 hours after the accident. That ambulance was from the Navajo Nation.[14] The injured were treated at 12 hospitals/medical centers and 1 clinic, as shown in table 2. The nearest Level I trauma center[15] was in Flagstaff, Arizona, approximately 190 miles away.

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[12] There are three categories of emergency service: basic life support (BLS), provided by personnel trained to be emergency medical technicians; ALS, provided by paramedics; and specialty care transport (SCT), provided by personnel trained to conduct critical care service beyond the scope of paramedics.

[13] Volunteer EMTs receive the same training as full-time EMT personnel.

[14] This was the only responding agency that would not comply with a subpoena for its transport records needed to reconstruct travel times.

[15] Level I trauma centers provide the highest level of surgical care for trauma patients and are staffed with surgeons and anesthesiologists 24 hours a day.

Table 2. Distribution of emergency medical facilities.

Facility	Trauma level[A]	Distance from site	Number of injured treated[B]
Blanding Family Practice **Blanding, Utah**	No trauma unit	43 miles	9
Kayenta Medical Clinic **Kayenta, Arizona**	No trauma unit	45 miles	2
San Juan Hospital **Monticello, Utah**	No trauma unit	75 miles	26
Chinle Comprehensive Healthcare Facility **Chinle, Arizona**	No trauma unit	115 miles	2
Allen Memorial Hospital **Moab, Utah**	Level IV	117 miles	5
Sage Memorial Hospital **Navajo Nation, Tuba City, Arizona**	No trauma unit	120 miles	2
San Juan Regional Medical Center **Farmington, New Mexico**	Level III	130	3
Flagstaff Medical Center **Flagstaff, Arizona**	Level I	190 miles	2
St. Mary's Hospital **Grand Junction, Colorado**	Level II	230 miles	10
Banner Good Samaritan Hospital **Phoenix, Arizona**	Level I	340 miles	2
Primary Children's Hospital **Salt Lake City, Utah**	Level I	360 miles	1
University Hospital **Salt Lake City, Utah**	Level I	360 miles	1
Intermountain Healthcare LDS Hospital **Salt Lake City, Utah**	Level I	360 miles	1

[A]Trauma centers are designated levels I–V, with level I providing the highest level of care based on American College of Surgeons criteria.

[B]The total number of injured treated is greater than the number of motorcoach occupants because several of the injured were moved between facilities.

A life-flight crew from St. Mary's Hospital was requested but was grounded due to weather conditions. A Classic Lifeguard helicopter from Page, Arizona, was also requested but could not fly due to the weather conditions in northern Arizona. At 11:24 p.m., San Juan Hospital in Monticello, Utah, requested that St. Mary's Hospital send an ALS ground ambulance. St. Mary's Hospital responded by having its life-flight crew, which consisted of a flight nurse, a paramedic, and a physician, travel approximately 169 miles by ambulance to San Juan Hospital. The ambulance then picked up two seriously injured passengers; one died en route to St. Mary's Hospital. The other fatality that did not occur at the accident scene involved a victim who died at Allen Memorial Hospital. That victim had been transported in a Grand County ALS ambulance that, while en route to Moab Airport to meet an airplane, was diverted to Allen Memorial Hospital in Moab due to the patient's deteriorating medical condition.

Southwest Memorial Hospital in Cortez, Colorado, sent two ALS ambulances with one paramedic in each to San Juan Hospital in Monticello, Utah, which is approximately 60 miles away. In addition, a physician from Southwest Memorial Hospital accompanied one of the ambulances to Monticello to assist that hospital's emergency room. Several seriously injured passengers were transported from San Juan Hospital by ambulance to Allen Memorial Hospital in Moab, Utah, and then taken to Canyonlands Field Airport in Moab for air medical transport to trauma hospitals in Salt Lake City.[16] The weather conditions in the area were poor, necessitating air transport into an airport equipped with a published instrument approach using aircraft capable of operating in instrument flight rules (IFR) conditions. Monticello Airport was not equipped with an instrument approach. Canyonlands Field Airport has an instrument approach, as does Blanding Municipal Airport in Blanding, Utah.

Shortly after the accident, on January 8, approximately 50 first responders, hospital staff, and local government officials met for an EMS debriefing in Bluff, Utah. On January 17, regional officials participated in a second postaccident review meeting in Monticello, Utah.

Emergency Preparedness

San Juan County, located in the southeast corner of the State, is the largest county in Utah in land mass with a total area of 7,933 square miles.[17] As of the 2000 census, 14,413 people resided in the county, or roughly 2 residents per square mile, making it one of the least densely populated counties in the United States.

San Juan County's emergency operations plan[18] did not contain a formal mass casualty incident plan but did have annexes that cover rescue and emergency medical services, mass fatalities, and shelter/mass care. Within those annexes are sections entitled "Situations and Assumptions" and "Concept of Operation," which outline recommended actions and contacts in the case of a disaster. The "Assumption" section in the "Rescue and Emergency Service" annex notes that any large-scale emergency would increase the demands of the volunteer EMS to the extent that any mass casualty event would overwhelm the limited response capabilities of San Juan County.

The Utah Department of Health, Bureau of Emergency Medical Service's Emergency Operations Plan includes a section entitled "Request for State and Federal Assistance," which states that State and Federal healthcare assets must be formally requested through the Utah Department of Health. The State Bureau of EMS participates in the Emergency Medical Assistance Compact, which is a signed State-to-State mutual aid agreement. In addition, Utah has established regional EMS support teams located around the State. On the day after the

[16] A flight of approximately 160 miles.

[17] Larger than the State of Connecticut.

[18] The county prepares the plan for Utah Department of Health approval.

accident, a regional support team from Price, Utah, arrived to relieve first responders who had been working through the night of January 6.[19]

Utah and San Juan County use the National Incident Management System (NIMS).[20] According to the San Juan County EMS Coordinator, both State and County personnel receive most of their NIMS training from the Federal Emergency Management Agency (FEMA). Beginning in 2007, all first responders receive NIMS IS 700 training, an introductory on-line course that explains the purpose, principles, and components of incident command systems and takes about 3 hours to complete. According to the San Juan County EMS Coordinator, the majority of its personnel have already received basic NIMS and NIMS IS 700 training.[21]

Weather

After starting the trip in Telluride with snowy and icy roads, driving conditions improved as the accident motorcoach drove west, then south. The Utah investigative officer who responded to the accident stated that road conditions at 9:20 p.m. at the accident scene were dry.

At 8:50 p.m., the San Juan County Sheriff's Office had contacted the Bluff Station road supervisor, who dispatched two plows/sanders to the accident scene for debris removal. The plow operators arriving on scene at 10:30 p.m. reported foggy conditions and the road at the crash site to be damp from rain. Temperature instruments mounted in one of the trucks reported a road surface temperature of 37° F and air temperature of 41° F.

Astronomical data obtained from the U.S. Naval Observatory for Blanding indicated that sunset was 5:14 p.m., end of twilight was 5:43 p.m., and, at the time of the accident, the sun was more than 15 degrees below the horizon. The phase of the moon was a waning crescent with only 3 percent of the moon's disk visible.

[19] Price is 240 miles from Mexican Hat. The EMS support team arrived in Monticello at 9:00 a.m. on January 7.

[20] NIMS provides a consistent nationwide template to enable all Government, private-sector, and nongovernmental organizations to work together during domestic incidents, as required by Homeland Security Presidential Directive 5 (February 28, 2003).

[21] NIMS is a national standard and a curriculum. Currently, six courses managed by FEMA are required for an individual or organization to be considered NIMS-compliant through FY 2007. Basic incident command system training consists of the four classroom courses (ICS 100, ICS 200, ICS 300, and ICS 400) and two independent study courses (IS 700, an introductory course for NIMS, and IS 800, an introductory course for the National Response Plan).

Driver Information

Driver Fitness

The 71-year-old driver resided in Michigan and had worked part-time for Arrow since March 2007. He possessed a valid Michigan commercial driver's license (CDL) with a passenger endorsement and a restriction limiting CDL use to class B/C vehicles only.[22] Michigan motor vehicle records indicated that the driver had no record of violations or accidents during the previous 5 years of motorcoach driving. Prior to driving motorcoaches, the driver had 7 years of CDL experience as a truck driver.

The driver's most recent medical examination report for commercial driver fitness determination, dated February 21, 2007, reported his visual acuity as 20/30 in both eyes evaluated together, without corrective lenses. The driver was 67 inches tall and weighed 235 pounds, and his medical report referred to a history of heart disease, heart surgery, and high blood pressure, indicating "heart bypass 1996" and "leg bypass 1998." The report noted "no" for "sleep disorders, pauses in breathing while asleep, daytime sleepiness, loud snoring." The report also noted, "due to hypertension, the driver qualified for only 1 year."

The driver's personal medical records[23] documented a history of atherosclerotic disease[24] with coronary artery bypass surgery in 1996 and angioplasty in 2005 as well as surgery to clear blockages in major arteries in both legs in 1998. A pharmacological stress test in 2006 showed no evidence of blocked coronary arteries at that time.

The driver's personal medical records also indicated a history of sleep disorders. He underwent a polysomnogram in January 2007 and was diagnosed with moderate obstructive sleep apnea. He was being treated with a CPAP device to assist with sleeping. Prior to treatment, he had complained of snoring, periods during which he stopped breathing at night, disturbed sleep, and sleepiness during the day. He had been on CPAP treatment for approximately 1 month at the time of his February 2007 commercial driver fitness examination,[25] but he marked "no" to the question asking if he had any history of "sleep disorders, pauses in breathing while asleep, daytime sleepiness, loud snoring" on the form documenting that examination.

[22] The expiration date on the license was December 8, 2011. A Michigan class B license applies to single vehicles with a gross vehicle weight rating (GVWR) of 26,001 pounds or more or a gross combination weight rating of 26,001 pounds or more, towing trailers/vehicles rated at 10,000 pounds GVWR or less. A class C license applies to vehicles under 26,001 pounds GVWR; vehicles that are designed to transport 16 or more persons including the driver; vehicles that carry 15 or fewer people (including the driver) transporting children to or from school and home regularly for compensation; or vehicles that carry hazardous materials in amounts requiring placarding.

[23] Dated May 22, 2006, January 5, 2007, and February 8, 2007.

[24] Often referred to as "hardening of the arteries."

[25] At the time of the accident, the driver had been using the CPAP device for 11 months.

The driver told the tour group leader, who was one of his passengers, that he had been sick for the 3 days in Telluride preceding the return portion of the accident trip.[26] The driver stated to investigators that, due to his head congestion, use of the CPAP device was difficult. The driver could not use the CPAP device the first night in Telluride and used it only sporadically the other 2 nights, adversely affecting his sleep for the 3 nights preceding the accident. The driver's activities in the 72 hours before the accident are shown in figure 7.

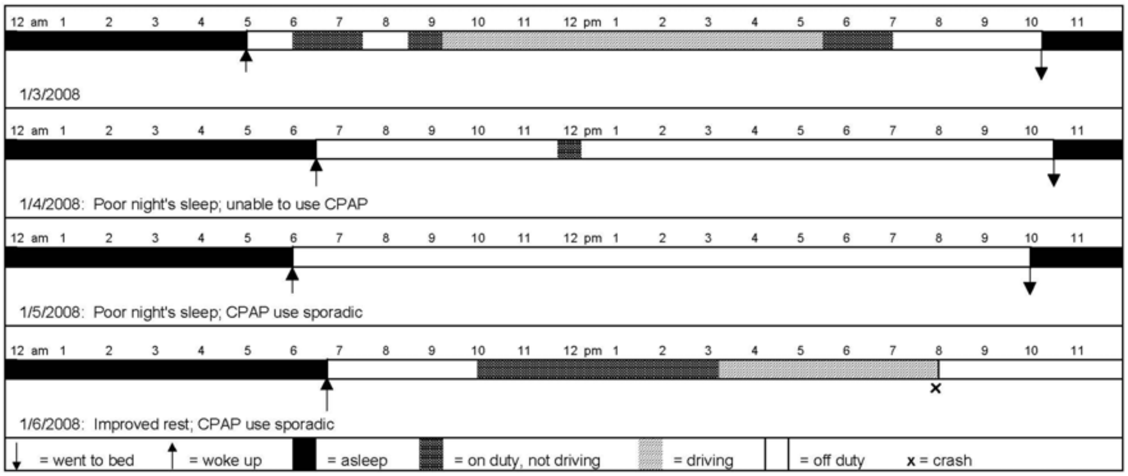

Figure 7. Accident driver's sleep and activity log. (Note: Black bars indicate time available for sleep, not necessarily sleep obtained. Driving time occurs within, but is not synonymous with, on-duty time.)

The driver reported to investigators that during the trip, he experienced what he described as a head cold, including a constant "runny nose." While he was in Telluride, the driver purchased the "non-drowsy" form of a cold medicine on two occasions and self-medicated throughout his stay. The driver stated that he did not use the medication on the day of the accident. Postaccident blood specimens were collected from the driver while he was hospitalized in Flagstaff, Arizona, for toxicological testing by the Civil Aerospace Medical Institute. These specimens tested negative for drugs and alcohol. The specimen samples were taken at 7:40 a.m. on January 7, nearly 12 hours after the accident. The police, lacking probable cause, did not administer any tests or require specimens from the driver.

Telluride, Colorado, is located at 8,750 feet altitude. On January 3, as the driver traveled from Phoenix to Telluride, he would have gained more than 7,000 feet in altitude. Resorts in Telluride caution visitors about the town's high altitude.[27] Headache, nausea, trouble sleeping, nasal congestion, and dizziness are symptoms of acute mountain sickness. One of the other drivers observed that the accident driver experienced some shortness of breath while installing tire chains on the morning of the accident.

[26] Another passenger reported that he overheard the driver's statement.

[27] See <http://www.telluride.com/the-mountain/high-altitude-information.html>.

Driver Performance

On the day of the accident, the driver awoke at 6:45 a.m., and after being awake for 8.5 hours, began the accident trip at 3:15 p.m. According to a passenger, the driver stopped to remove tire chains about 20–30 minutes after leaving Telluride; he was unable to complete that task without the assistance of several passengers and another Arrow driver. Given the rerouting and weather conditions, the trip would have taken at least 11 hours.[28] According to passenger interviews, the driver said that the trip to Phoenix would take about 12 hours, with an anticipated arrival time between 3:00–4:00 a.m. Interviewed passengers mentioned that earlier in the accident trip, the driver drifted onto the shoulder, running over the rumble strips.[29] Several expressed concern to each other about the motorcoach's speed. They also reported that earlier in the trip, when the motorcoach was south of Blanding, the driver swerved and objects inside the bus shifted and that one of the passengers yelled "slow down" to the driver. The DriveCam II video event data recorder[30] from the motorcoach recorded another passenger saying "slow down" 2.75 seconds before the accident.

The Safety Board received a transcript of a tape-recorded interview of the driver by the Utah Highway Patrol Officer on scene following the accident. In that interview, he stated that he had the cruise control set at 65 or 66 mph. Safety Board investigators interviewed the driver 6 days after the accident, following his release from the hospital. The driver said that he thought he may have been going too fast for the curve, but he was not speeding and was driving at a speed of 65 mph or less.

Investigators reviewed the DriveCam II video recording of the passengers and motorcoach's interior. The driver can be seen in the video; however, the video recording rate of 4 images per second was insufficient to determine the driver's gaze location, duration, or the length of eye closures. The view of the driver is from about mid-chest level upward. His upper-right arm and shoulder are visible but not his hands or the steering wheel. The video shows the driver making a steering input in the beginning of the accident curve. His shoulders and right upper arm rotate slightly to his left, and his head turns toward the left. Accelerometer data indicate the vehicle turns toward the left. The driver's head remains in this leftward position from this time until the accident. After this initial input, little or no movement of the driver's arms or shoulders occurs for the next 3 seconds. The driver then makes a larger shoulder and arm rotation to the left, which is held relatively constant until the collision occurs, about 4.75 seconds later. As the motorcoach departs the roadway, passengers exhibit looks of alarm and brace themselves. The driver reacts more slowly than the passengers.

[28] The outbound trip from Phoenix to Telluride was slightly longer than 9 hours, based on the driver's log. The driver left Telluride at 3:15 p.m.; the accident occurred about 5 hours later. The remainder of the trip to Phoenix is 340 miles and would have taken 6 hours.

[29] The section of the road where the accident occurred did not have rumble strips. This comment applied to an earlier portion of the route.

[30] For more information on the DriveCam II video recorder, see "Data Recording Equipment" in the "Vehicle Information" section of the Factual portion of this report.

Motor Carrier Operation

Busco, Inc., doing business as Arrow Stage Lines, is an interstate, authorized for-hire carrier of passengers headquartered in Norfolk, Nebraska, with business locations in seven western States. The family-owned business, which was established in 1928, has 48-State and Canadian authority.[31] Arrow also provides military transportation between bases in Kansas and Missouri. Arrow purchased a charter company in Phoenix called "Corporate Transportation 'N Tours,"[32] which was the terminal from which the accident motorcoach operated.

Arrow operates 179 motorcoaches in both scheduled and charter service using a mixed fleet of Setra, MCI, Prevost, and VanHool motorcoaches and smaller buses and vans. The average age of Arrow's motorcoach fleet is 5 years. The company employs 337 drivers. The average age of Arrow drivers is 60. Single-day drivers are paid by the hour, and overnight charter drivers are paid a flat daily rate plus expenses.

Oversight and Compliance Reviews

The Federal Motor Carrier Safety Administration's (FMCSA's) January 19, 2006, compliance review of Arrow, conducted before the accident, resulted in an overall "satisfactory" rating. That review included "conditional" ratings for Driver and Vehicle factors. At that time, Arrow had an accident rate of 0.37 accidents per million miles traveled.[33] The FMCSA's Motor Carrier Management Information System (MCMIS) database indicated that Arrow had also received compliance reviews in 1991, 1996, and 2000, all resulting in satisfactory ratings.

The FMCSA conducted a postaccident safety fitness compliance review of Arrow on February 2, 2008. That on-site review resulted in an overall conditional rating, meaning that the carrier did not have adequate safety management controls in place to ensure compliance with the safety fitness standards.[34] The conditional rating was the result of Arrow being rated less than satisfactory in three areas: Factor 2—Driver (conditional), Factor 4—Vehicle (conditional), and Factor 3—Operational (unsatisfactory). The review found that Arrow failed to conduct postaccident alcohol and drug testing on the accident driver, all 16 drivers completing the accident-related trip had hours-of-service violations, and Arrow was using a commercial motor vehicle not periodically inspected. These are all critical elements in determining a carrier's safety rating. Records from that review show that Arrow traveled 10,333,556 miles in 2007; during that time, the company had 6 reportable accidents, resulting in 0.58 accidents per million miles traveled. The FMCSA has determined that motor carriers with an accident rate of 1.50 or greater are deficient. A followup to the postaccident review was conducted on August 18, 2008, resulting in a satisfactory rating.

[31] U.S. Department of Transportation identification number 433377 and motor carrier number 232723.

[32] Arrow purchased the charter company on February 1, 2005.

[33] Title 49 CFR Part 385 B(c) defines deficient motor carriers as those with an accident rate above 1.50 accidents per million miles traveled.

[34] Title 49 CFR Parts 40, 325, 350, and 355–399.

In addition to the MCMIS, the FMCSA uses the Motor Carrier Safety Status Measurement System (referred to as SafeStat) to evaluate the safety posture of a motor carrier and to determine which motor carriers should be scheduled for compliance reviews. Of the eight SafeStat performance levels, only three would trigger compliance reviews. According to FMCSA, Arrow's most recent SafeStat scores showed the carrier not to be deficient.[35]

Roadside inspection data for the 12 months before the accident showed that Arrow had 180 vehicle inspections with 7 vehicles placed out of service (4 percent) and 80 driver inspections with 2 drivers placed out of service (2.5 percent). The national averages are 23 percent for vehicle inspections and 7 percent for driver inspections. The FMCSA uses an inspection selection system (ISS) program to aid roadside inspectors in selecting vehicles for inspection. The ISS rating system has been combined with the SafeStat system, resulting in a more uniform system, called ISS-D, which categorizes operators as follows: pass (no inspection recommended), optional, or inspect.[36] Before the accident, Arrow received a "pass" rating in the system; as a result of the postaccident compliance review, Arrow was rated as "inspect" for roadside inspections. As of September 26, 2008, Arrow's score was 73 (optional).

The Military Surface Deployment and Distribution Command of the U.S. Department of Defense contracts with a private company, Consolidated Safety Services Incorporated, to conduct facility, terminal, and vehicle inspections of motor carriers that transport military personnel. Consolidated Safety Services conducted a comprehensive audit of Arrow on October 9, 2007, in which Arrow received a rating of 1, the highest rating on a scale of 1–5.

Hours of Service

Hours-of-service regulations generally require carriers and drivers of passenger-carrying commercial motor vehicles not to exceed 10 hours of driving time following 8 consecutive hours off duty, except under adverse driving conditions. The hours-of-service regulations define adverse driving conditions as snow, sleet, fog, or other adverse weather conditions; a highway covered with snow or ice; or unusual road and traffic conditions, none of which were apparent on the basis of information known at the beginning of the accident trip. Under adverse conditions, a passenger-carrying driver en route to a destination is permitted to drive a commercial motor vehicle up to 2 additional hours to complete that run or to reach a place offering safety for the occupants of the commercial motor vehicle and security for the commercial motor vehicle and its cargo. However, drivers of passenger-carrying commercial motor vehicles may not drive or be permitted to drive for more than 12 hours total following 8 consecutive hours off duty.[37] If a motor carrier or a driver is aware of adverse weather before departing on a trip, as would have been the case for the accident trip because of the lead driver's knowledge of the road closure, the

[35] As of December 19, 2007, Arrow scored as follows in these areas: 13.01—Accident, 33.97—Driver, and 6.43—Vehicle. A carrier scoring 75 or above in two or more areas warrants a compliance review. After the postaccident compliance review, Arrow scored higher than 75 in two areas (Driver—93.13 and Safety Management—89.53), prompting the followup review conducted in August 2008.

[36] ISS-D score ranges are 1–49 (pass), 50–74 (optional), and 75–100 (inspect).

[37] 49 CFR 395.1(b)(iii), adverse driving conditions.

adverse weather rule allowing 12 hours does not apply.[38] The FMCSA's postaccident compliance review found that 14 drivers exceeded the 10-hour driving rule and the 2 other drivers had false reports of duty status for the trip from Telluride, Colorado, to Phoenix. Arizona.

Trip Communications

Arrow normally provides Nextel wireless telephones to its drivers on trips involving multiple motorcoaches.[39] Nextel units were not provided to the drivers for the accident trip because Nextel service coverage is very limited in the geographic area covered by the charter trip. Instead, drivers were encouraged to use personal wireless telephones to communicate with other drivers during the trip when coverage was available. A review of the motorcoach's internal video recorder, DriveCam II, conclusively established that the driver was not using a wireless telephone at the time of the accident.

An interview with the Arrow Safety Director confirmed that the lead driver had discussed plans for the return trip with the company on the day of the accident. Despite the fact that road closures due to heavy snowfall and avalanche risk are a common occurrence during winter months in the mountains, Arrow did not present the drivers with a contingency plan. The drivers did not request relief drivers, and Arrow did not arrange for them.

Vehicle Information

The accident motorcoach was a 2007 Motor Coach Industries, model J-4500, 56-passenger, three-axle, intercity motorcoach, delivered into service June 30, 2007, and registered in Nebraska. The total vehicle mileage was 23,941, and the gross vehicle weight was 54,000 pounds. The vehicle was equipped with a DriveCam II video event data recorder (VEDR) and a video entertainment system.

The motorcoach was powered by a six-cylinder Caterpillar diesel engine equipped with a Jacobs Engine Brake[40] and cruise control. In a postaccident interview with investigators, the driver stated that the "jake brake" was not engaged and it was not his practice to use it in changing road conditions (wet to dry). The vehicle had a conventional air brake system with disc brakes on all three axles. A postaccident visual inspection of the braking system was conducted,

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[38] The FMCSA's interpretation of the hours-of-service regulations, guidance no. 5, states: "An absolute prerequisite for such claim must be that the trip involved is one of which could normally and reasonably have been completed without a violation and that the unforeseen event occurred after the driver began the trip. Drivers who are dispatched after the motor carrier has been notified or should have known of adverse driving conditions are not eligible for the two hours additional driving time provided under 396.1(b), adverse driving conditions."

[39] The Arrow employee manual states that cellular telephones should be used only when absolutely necessary and only for work-related communication.

[40] An engine brake, often referred to as a jake brake, is a device that uses air compression to change the timing of the engine exhaust valves. The retarding power is proportional to the engine speed (rpm) and results in lower control speed in downhill descents with reduced use of the foundation braking system.

and no audible leaks were detected from the pressurized system.[41] The front wheels/tires were removed from the motorcoach, and an operational check of the brakes was performed by applying the service brake (regular brake pedal) in the driver's compartment. When rotated, the hubs stopped when the brakes were applied. Because the automatic adjusting mechanism is integrated in the body of the disc brake system, there were no pushrods to be measured. No appreciable wear was found on the rotors,[42] and the measured brake pads were well within wear limits.[43] The vehicle was equipped with a Meritor-WABCO six-channel automatic braking system but did not have electronic stability control.

The motorcoach was equipped with manufacturer-recommended-size tires,[44] with more than adequate tread depths.[45] The front tires remained inflated after the accident sequence, measuring 105 psi each; of the remaining six tires, four were deflated as a result of being off the bead or off the rim. Two tires on the middle dual-wheel drive axle measured 101 psi and 105 psi.

The steering system was found to have adequate fluid; there were no indications of power steering fluid leaks. A portion of the steering assembly was damaged, consistent with accident damage.[46] In a postaccident interview, the driver stated that he experienced no handling problems with the motorcoach.[47]

The DriveCam II video recording confirmed that the vehicle headlights were on. Testing of the headlight bulbs for filament distortion to determine whether the lights were on high or low beam was inconclusive. The setting of the high-beam steering wheel spring switch before the accident could not be confirmed, and no vehicle record of the setting was available.

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[41] The brake air system retained air pressure at 70 psi after the accident.

[42] The front rotors were without cracks, and the rotor thickness was measured at 1.75 inches for the right-front brake and 1.77 inches for the left. Both measurements were similar to the approximately 1.75 inches found on a new rotor.

[43] The brake pads were pulled and measured and none of the front brake pads exhibited heat damage. The right-inside pad measured 0.64 inch and the right-outside pad measured 0.62 inch; the left-inside pad measured 0.62 inch and the right-inside pad measured 0.64 inch, all well within the legal wear limit of 0.125 inch (1/8 inch) as required by the *Federal Motor Carrier Safety Regulations* (FMCSRs), Section 393.47.

[44] Firestone model FS-400 radial tires that had an "L" speed rating (75 mph) and a "J" load rating (8,270 pounds at 120 psi).

[45] The tires, when new, have tread depths of 0.562 (18/32) inch. The postaccident tread depths measured between 0.312 (10/32) and 0.562 (18/32) inch. FMCSR 393.75 states that any tire on the front wheel of a bus shall have a tread groove pattern depth of at least 4/32 inch, and all other tires shall have a tread groove pattern depth of 2/32 inch.

[46] The steering shaft was disconnected from the U-joint on top of the miter box. The upper-front spare tire truss supporting the miter box was bent upward. One of the inner flanges of the U-joint had metal chipped away, and the end of the cross pin had pin indentations. The fresh markings on the cross pin showed that it had been fully engaged in the U-joint.

[47] In a statement to the Utah Highway Patrol, the driver stated, "excellent equipment…new bus…handled like a dream."

Roof Design

According to an MCI representative, the accident motorcoach, as well as others that MCI manufactures, was constructed using a monocoque-type frame. Monocoque construction offers a weight advantage and is commonly utilized in motorcoaches and van-type semitrailers, in which the sides of the vehicle bear a substantial part of the load in shear. The roof panel was made of aluminum and secured to the stainless steel roof bows using structural adhesive; the edges of the panel and the periphery of the roof hatches were riveted. The roof had five longitudinal supports running from the front-upper structure to the rear-upper structure. The roof was supported by eight stainless steel posts on each side, which extended vertically from the belt rail to the roof rail and were welded at the belt rail and again at the roof rail. Although not a single continuous tube, the eight vertical posts continued across the roof, becoming roof bows. Figures 8 and 9 illustrate segments of the motorcoach's roof and side construction.

The roof of the motorcoach became detached from the body during the rollover. The motorcoach rotated about its longitudinal axis, rolling over 360 degrees to its right, and approximately 180 degrees about its vertical axis, stopping on its wheels facing east. During the rollover, the right side of the motorcoach's roof, at the lower edge of the window sill (sash rail) and vertical support posts for the window, became separated from the body. At final rest, the motorcoach was right side up, with the roof lying on the ground near the motorcoach, top side down. The windshield glazing and all windows along both sides of the motorcoach were displaced during the rollover.

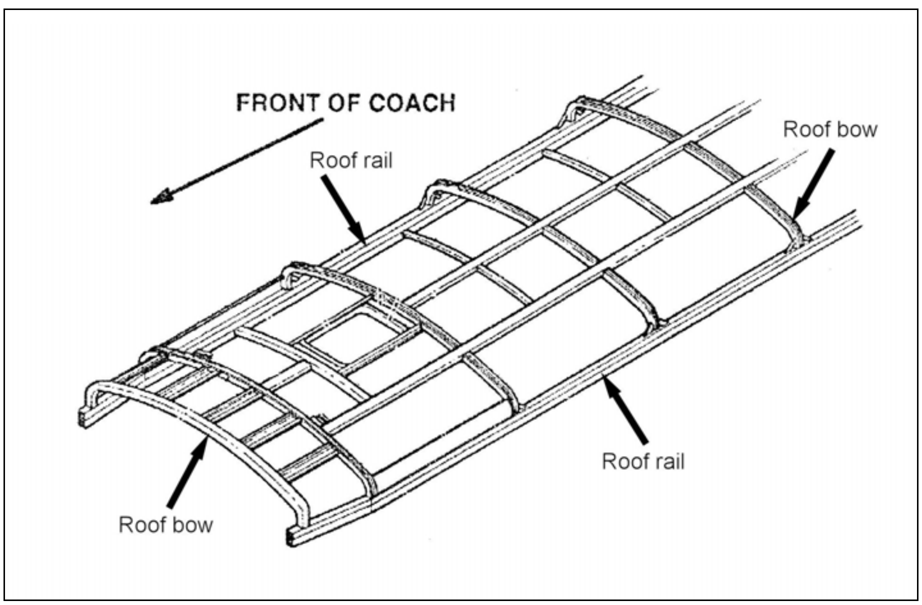

Figure 8. Motorcoach roof design. (Source: MCI.)

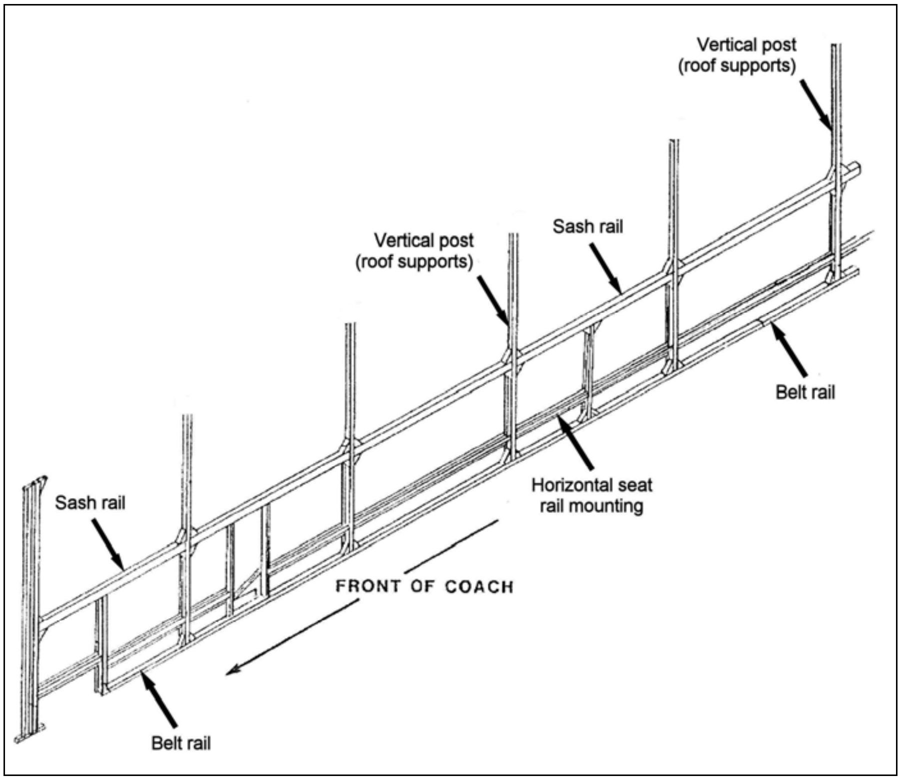

Figure 9. Motorcoach side supports for roof. (Source: MCI.)

Data Recording Equipment

The accident vehicle was not equipped with an advanced event data recorder capable of detailed accident reconstruction, nor was it required to be. The electronically controlled engine did have an advanced electronic control module (ECM)[48] capable of recording selected vehicle movement and performance information. The engine, as delivered by Caterpillar, had the ECM data recording function turned off and did not capture vehicle speed, rpm, or braking information at the time of the accident.

Although not configured to record "quick stop" data, the ECM was capable of logging data associated with critical diagnostic events. Logged diagnostic data include information on when the event started, how long it was active, the extreme value, and the average values. ECM data extraction determined that the accident vehicle's maximum speed had been recorded at

[48] An ECM is a semiconductor unit for controlling ignition timing, fuel delivery, speed control, and other parameters related to the engine management system. It is capable of logging data associated with critical diagnostic events. This capability is not intended to capture crash data, but to assist technicians in trouble-shooting system fault conditions.

88 mph. It could not be determined from ECM data when, over the life of the vehicle, that maximum speed occurred.[49] ECM calibration and configuration data revealed that the cruise control feature of the ECM was enabled, with a maximum potential cruise speed of 72 mph. It could not be determined whether the electronic controls integrated in the steering wheel for the cruise control and the Jacobs engine brake were engaged at the time of the accident.

The motorcoach was also equipped with a Saucon on-board global positioning system (GPS) and telemetry system capable of transmitting time-tagged location information. During recovery of the motorcoach on the day after the accident, the wrecker operator disconnected the vehicle battery, resulting in permanent and total loss of quick-stop data.[50]

The DriveCam II system incorporated digital recording capability that successfully captured interior and exterior video, audio, and dual-axis accelerometer (longitudinal and lateral)[51] parametric data at the time of the crash. A detection of lateral acceleration of 0.45 g would have started a 20-second video and data recording. There was only one DriveCam II recording between Telluride and Mexican Hat, the one from the accident event, meaning that the camera did not sense any events that exceeded the thresholds prior to the accident. The DriveCam II video recorder utilized an internally housed 64-megabyte compact flash memory card to store video, audio, and accelerometer data. A review of the external video footage showed the motorcoach gradually departing the pavement to the right as the roadway curved to the left. No other vehicle or obstacle was involved.[52]

Road Design

In southeastern Utah, U.S. 163 is a two-lane, asphalt-paved, secondary rural road with an average daily traffic count of 650 vehicles per day. The roadway forms part of the Trail of the Ancients National Scenic Byway and cuts through the heart of Monument Valley. Although the roadway is mainly straight, there are numerous curves and steep grades. The road is marked with a centerline and white edge lines and route delineator posts with reflectors. The surrounding terrain is rough with varying elevation.

Shortly after the driver missed the U.S. 191 turn, and 10 miles before the accident site, U.S. 163 becomes a long downhill stretch (5-percent downgrade) beginning at approximately milepost 39.[53] At the beginning of the downgrade, the driver would have experienced a sharp

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[49] The recording of a maximum speed in the ECM could occur during loss of traction and may not reflect a valid road speed.

[50] Data storage in the unit was accomplished through volatile (internal random access) memory, requiring an uninterrupted power supply to maintain memory storage.

[51] An accelerometer is an electromechanical device that measures the magnitude and direction of acceleration and gravity-induced reaction forces.

[52] A discussion of the motorcoach's internal video recording appears in "Driver Performance" in the "Driver Information" section of the Factual portion of this report.

[53] Milepost numbers decrease on approach to the accident site.

horizontal curve that was well marked with chevron curve signs[54] and a 35-mph speed advisory warning. Beginning 4 miles before the accident site, about milepost 33, the highway begins a gradual descent,[55] as shown in figure 10. The immediate approach to the curve where the accident occurred is a long, straight downgrade (1,200 feet long with a 5.6-percent downgrade), as shown in figure 11.

Figure 10. View of descending road grade, 4 miles before the accident site.

[54] Chevrons are geometric shapes (<< >>) that indicate direction.

[55] For more than a mile (6,400 feet) preceding the curve where the accident occurred, the highway averages a 4-percent downgrade.

Figure 11. View of descending road grade in the direction of travel, immediately preceding the accident curve.

The accident occurred on a long left-hand curve that extends for nearly one-third of a mile (1,641 feet) at milepost 29. The curve, shown in figure 12, has a spiral transition and a 1,400-foot radius resulting in a 4-degree curve. The curve had a 6-percent superelevation or bank. A curve warning sign is posted on the right-hand roadside approximately 750 feet in advance of the curve.[56] The curve warning sign does not have a posted advisory speed warning sign. The posted speed for the area is 65 mph.

[56] The curve sign is 12 feet from the roadside and 7 feet above the pavement.

Figure 12. View of accident curve.

The highway design plan indicates that this section of the roadway has a 60-mph design speed. In December 1996, ball-bank indicator tests[57] were performed on this curve at the 65-mph speed limit, and a reading of less than 10-degree angle was observed,[58] indicating that the reduced advisory speed did not need to be posted on this curve.[59]

The accident curve had a W-rail, weak-post guardrail[60] erected 220 feet after the beginning of the curve. The guardrail, shown in figure 13, continued for approximately 550 feet along the right side of the road in the first half of the curve and was marked with reflectors. The guardrail provided vehicle protection from a drainage culvert at the toe of the slope, and the foreslope had a 1V:2H drop.[61] This slope would be classified as critical, meaning that an errant

[57] The term *ball-bank indicator* refers to an inclinometer used for the specific purpose of determining safe curve speeds for horizontal curves. It measures the overturning force (side friction), measured in degrees, on a vehicle negotiating a horizontal curve.

[58] The minimum radius for a curve under these conditions is 1,348 feet. The road's actual curvature is 1,432 feet.

[59] *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials (Washington, DC: AASHTO, 1994) page 144.

[60] Weak-post guardrails provide larger dynamic deflections in a collision and are considered more forgiving than stiffer barriers.

[61] The slope dropped 1 foot vertically for every 2 feet of horizontal distance.

vehicle running off the road onto the slope would likely overturn. The existing guardrail had no end treatment.[62]

Figure 13. View of guardrail.

On the left side of the road, approximately halfway through the curve, a bluff that is 20–30 feet high extends across the landscape and up to the road's edge. That terrain blocked the driver's view of the route delineator posts marking the last 500 feet of the curve. Likewise, as the road curved to the left behind the bluff, the motorcoach headlights would not have illuminated reflectors on the route delineator posts.

For approximately 200 feet after the guardrail, the terrain on the right side of the road rose into a 3-foot-high mound that was traversable and would serve to help an errant motorist regain control. A little over halfway through the curve, the foreslope again fell away from the side of the road bed at a rate of 1V:3H, a flatter slope. Guidance in the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide* indicates that this slope is considered traversable but not recoverable.[63] The *Roadside Design Guide* also indicates that a slope of this magnitude would not have been required to have a longitudinal barrier or guardrail unless some other hazard was located on the slope or in the clear zone.

[62] The American Association of State Highway and Transportation Officials *Roadside Design Guide*, Section 9.2.2, identifies standard guardrail end treatments. For further information, see American Association of State Highway and Transportation Officials, *Roadside Design Guide* (Washington, DC: AASHTO, 2006).

[63] In other words, an errant motorist would likely follow the slope down.

Accident Location History

Records for the 5-year period from 2002–2006 showed that 10 other accidents had occurred along the 4-mile-long stretch from mileposts 28–32. Four of these accidents were property damage only and six involved injuries but no fatalities. One accident occurred on the accident curve. One accident involved a truck; no motorcoaches were involved in that 5-year period.

Further Utah Department of Transportation (UDOT) research found a record of a fatal accident involving a passenger car that had occurred on the accident curve in February 1997; in that accident, the driver had a blood alcohol concentration of 0.17 and, according to accident reconstruction, was traveling approximately 93 mph when he lost control of the vehicle.

Rural Versus Urban EMS Response

Most U.S. residents (approximately 85 percent) can reach either a level I or level II trauma center within an hour, but that proportion drops to 24 percent if only residents living in rural areas are considered. According to the National Highway Traffic Safety Administration (NHTSA), nearly 60 percent of all trauma deaths occur in rural areas,[64] where 20 percent of the nation's population lives. According to the National Academy of Sciences, the relative risk of a rural resident dying in a motor vehicle accident is 15 times greater than in urban areas, after adjusting for accident statistics, age, and gender. [65]

NHTSA's technical report on rural and urban crashes,[66] based on Fatality Analysis Reporting System (FARS) data from 1994–2003, reported that 218,539 fatal rural road accidents occurred during this 10-year period, resulting in 249,986 fatalities. The report states that proportionally more accidents occur in rural areas than in urban areas despite the fact that fewer miles are driven in rural areas, and rural accidents are more severe and cause greater injuries.

The Safety Board's recent data report, which was particular to the type of vehicle involved in the Mexican Hat accident, also found greater risk to charter/tour bus occupants involved in rural road accidents. That report, *Large Bus Accidents and Injuries in Rural and Urban Areas, 2000-2007*, is discussed in the Analysis section and presented in appendix B.

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[64] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Contrasting Attributes Between Rural and Urban Fatal Crashes, 1994–2003*, Technical Report DOT HS 809 896 (Washington, DC: NHTSA, 2005).

[65] *Emergency Medical Services: At the Crossroads,* Institute of Medicine of the National Academies (Washington, DC: National Academies Press, 2007).

[66] DOT HS 809 896.

AASHTO Strategic Highway Safety Plan

The AASHTO Strategic Highway Safety Plan[67] identifies 22 key emphasis areas (goals) that affect highway safety and focus attention on selected strategies to reduce highway fatalities.[68] One of the 22 goals, *Enhancing Emergency Medical Capabilities to Increase Survivability* (#20), consists of five areas to be researched and evaluated. If an area is found to be effective, funding for it would be expanded nationally. The five areas to be researched are as follows:

> Strategy 20A: Develop and implement a model comprehensive approach that will ensure appropriate and timely response to the emergency needs of crash victims.
>
> Strategy 20B: Develop and implement a plan to increase education and involvement of EMS personnel in the principles of traffic safety.
>
> Strategy 20C: Develop and implement an emergency preparedness model in three high-incident interstate highway settings (urban, rural, and wilderness).
>
> Strategy 20D: Implement and/or enhance trauma systems.
>
> Strategy 20E: Develop and support integrated EMS/public health/public safety information and program activities.

SAFETEA-LU and High-Risk Rural Roads

The U.S. Department of Transportation's Federal Highway Administration (FHWA) targets rural road safety through the High Risk Rural Road Program funded by the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). SAFETEA-LU establishes, in law, the requirements and funding for highway safety programs at the Federal and State levels from fiscal years 2006–2009. Each State must develop and implement a "Strategic Highway Safety Plan" that specifically identifies its Highway Safety Improvement Program (HSIP). Rural road safety improvements that are funded by SAFETEA-LU are treated as candidate HSIPs, which States can address in their annual Strategic Highway Safety Plans.[69]

Proposed HSIPs identify highway safety improvements and can help guide a State's investment decisions to achieve a significant reduction in fatalities and serious injuries on rural roads. HSIPs generally target highway infrastructure and span a wide range of improvements,

[67] See <http://safety.transportation.org/elements.aspx>.

[68] State and Federal safety and transportation officials aim to reduce the fatality rate from 1.5 to no more than 1.0 fatality per 100 million vehicle miles traveled.

[69] 23 CFR 148.(a)(3)(B)(xxi).

including lane and shoulder widening, rumble strips, skid-resistant road surfaces, traffic calming, or the removal of a roadside obstacle. Not all projects must be related to infrastructure improvement or highway construction; for example, one type of HSIP would be to improve the collection and analysis of crash data.

In developing HSIPs, States must adhere to SAFETEA-LU's requirement to incorporate a data-driven, analytical approach to highway safety based on traditional approaches to risk assessment that define risk in terms of accident frequency and accident severity. SAFETEA-LU requires each State to include in its Strategic Highway Safety Plan a crash data system, an analysis of hazardous locations and roadway elements, criteria for establishing the severity of locations, priorities for corrective action based on data analysis, and a data-driven means for evaluating the effectiveness of HSIPs.

In its published guidance, the FHWA outlines a two-step process for identifying high-risk rural roads and selecting projects.[70] The first step requires a State to identify eligible roadways with accident rates for fatalities and incapacitating injuries that exceed statewide averages for their respective roadway functional classifications. Accident rates must be based on crash data and on exposure data; typically, vehicle miles traveled (VMT), average daily traffic (ADT), and lane miles are considered exposure data, although States working toward a comprehensive statewide data system may use other sources for exposure data. States may also consider roads with a potential for increased traffic volumes and subsequent increase in accidents and fatalities.

The second step in the identification and selection process requires a State to use the eligible set of roadways identified in the first step to determine appropriate safety improvements and select projects. These projects form the basis for the HSIPs that appear in a State's Strategic Highway Safety Plan.

Utah Highway Safety Improvement Program

UDOT's 2007 annual report summarizes the Utah Comprehensive Safety Plan,[71] which includes four emphasis areas, including roadway departure crashes.[72] Emphasis areas were identified based on Utah accident data, and locations selected for highway improvements were identified based on the high-proportion testing method[73] rather than on accident rates. For

[70] For FHWA guidance on the High Risk Rural Roads Program, see <http://safety.fhwa.dot.gov/safetealu/hrrpattachment.htm>.

[71] Utah's version of the federally required Strategic Highway Safety Plan.

[72] These emphasis areas form the basis of the "Utah 2007 Five Percent Report." Other emphasis areas are the use of safety restraints, impaired driving, and aggressive driving.

[73] Generally, for each highway segment, the probability that a specific crash type was proportionally higher than the average for roads belonging to the same functional class (that is, two-lane highways) was computed based on the binomial test. If this probability was greater than would be expected by chance, the site was flagged and the number of crashes of a specific type out of the total number of crashes at that site was reported. For example, a value of 8/10 would mean that there were 8 crashes of that crash type out of a total of 10 crashes at that site, meaning that the proportion is substantially greater than expected to occur strictly by chance. This screening method identifies highway segments that have a high proportion of a target collision (that is, emphasis area) in relation to all collisions

roadway departure crashes, Utah has identified the 5 percent of roadway locations exhibiting the most severe safety needs and prioritized these locations for improvements such as rumble strips, signing, and education. All four improvement projects[74] target 155 miles of roadway along interstate road segments: three along Interstate 70 and one along Interstate 15.

Tests and Research

Vehicle Speed Analysis

The vehicle did not have an event data recorder, and vehicle performance data, as captured by the ECM, was limited. Consequently, the video record of the motorcoach departing the highway provided the best evidence of the event, and the Safety Board was able to develop a method for using those data to derive a speed estimate. Because the Safety Board does not have a history of using this analytical approach to calculate speed, several confirmatory analyses were also conducted. The three methods discussed in the following sections all corroborate the extreme speed of the motorcoach.

To estimate the speed of the motorcoach just before departing the roadway, the Safety Board's vehicle performance staff conducted an analysis of the video data taken from the motorcoach's DriveCam II video recorder. The analysis matches video image data with fixed survey points from the accident scene to establish the motorcoach's location in relation to time. A full discussion of the video study for this accident is presented in appendix C. That analysis determined that, 4 seconds before it departed the roadway, the accident motorcoach was traveling approximately 88 mph.

The DriveCam II video recorder continuously records color images in 640x360 format, at as high a rate as possible, which can vary between 10 and 30 frames per second. At any time, there is an image in the image sensor buffer's memory; these images are updated continually as new ones become available commensurate with the recording rate. The camera uses a 0.25-second timer to retrieve images from the buffer for storage into flash memory. Consequently, the actual timing difference between two adjacent stored images may vary from 0.15 second to 0.35 second;[75] that is, there is a potential timing error of up to 0.1 second relative to the nominal timing period of 0.25 second. When a continuous sequence of images is

within a functional class for serious and fatal injury crashes. The high proportion testing method is an effective way to evaluate crash history when traffic volume data are insufficient to facilitate the use of crash rates.

[74] The projected cost for the improvements to the four interstate segments was $650,000.

[75] The worst-case variance occurs at the slowest image acquisition rate of 10 times per second. If the timer selects an image from the buffer that is "old" by 0.09999 second and then 0.25 second later, selects a just-refreshed buffer image (age 0.00001 second), the actual recording time between the two images can be as long as 0.34999 second. Conversely, if the timer selects a just-refreshed image recorded at 0.00001 second and 0.25 second later, it selects an "old" image, the difference in recording times between such images can be as short as 0.15001 second.

considered, the timing error remains ±0.1 second relative to the total duration of the continuous sequence of images.

The DriveCam II video recording starts 10 seconds before the triggering event and lasts 10 seconds after the event, generating a total of 81 frames.[76] A triggering event is an acceleration that exceeds threshold.[77] The DriveCam II system includes one forward- and one rearward-facing camera. Only the video from the forward-facing camera viewing the roadway was used in the speed analysis. Safety Board staff calibrated the camera and mathematically corrected for distortion associated with its wide-angle lens.

On January 14–15, 2008, the Safety Board, UDOT, and Utah Highway Patrol staff used survey equipment consisting of a Trimble Robotic Total Station and Trimble 5800 receivers to take precise measurements of the accident scene. (This information is depicted in the scene diagram in figure 4.) Those survey data provided 183 fixed points (points on solid white lines, solid and broken yellow lines, and reflector locations) for use in the video study. Particularly useful reference points were the 12 reflectors that were mounted on a guardrail.

The analysis determined the location of the moving vehicle by comparing locations of landmarks in the camera image with their locations in a mathematically synthesized image based on surveyed data. If, at an assumed vehicle location, the camera image landmarks and synthesized image landmarks coincide, then the vehicle location is assumed to be where the vehicle was when the camera image was acquired. Vehicle speed was then estimated by "driving the distance" between locations within a timeframe corresponding to camera image frames.

Motorcoach locations were estimated at 19 known vehicle positions (18 intervals) corresponding to the time period -8.75 to -4.25 second relative to the triggering event. A speed estimate based on exact 0.25-second timing of the camera frame intervals was calculated, as well as upper and lower speed estimates that take into account the potential ±0.1 second timing error. The lower bound of the estimated speed at the end of the considered time period was 88 mph. (See figure 14.)

[76] 10 seconds x 4 frames per second + 1 frame of the triggering event + 10 seconds x 4 frames/per second = 81 frames.

[77] The threshold settings were 0.5 g for forward acceleration, 0.45 g for lateral acceleration, and 1.5 g for shock in either direction.

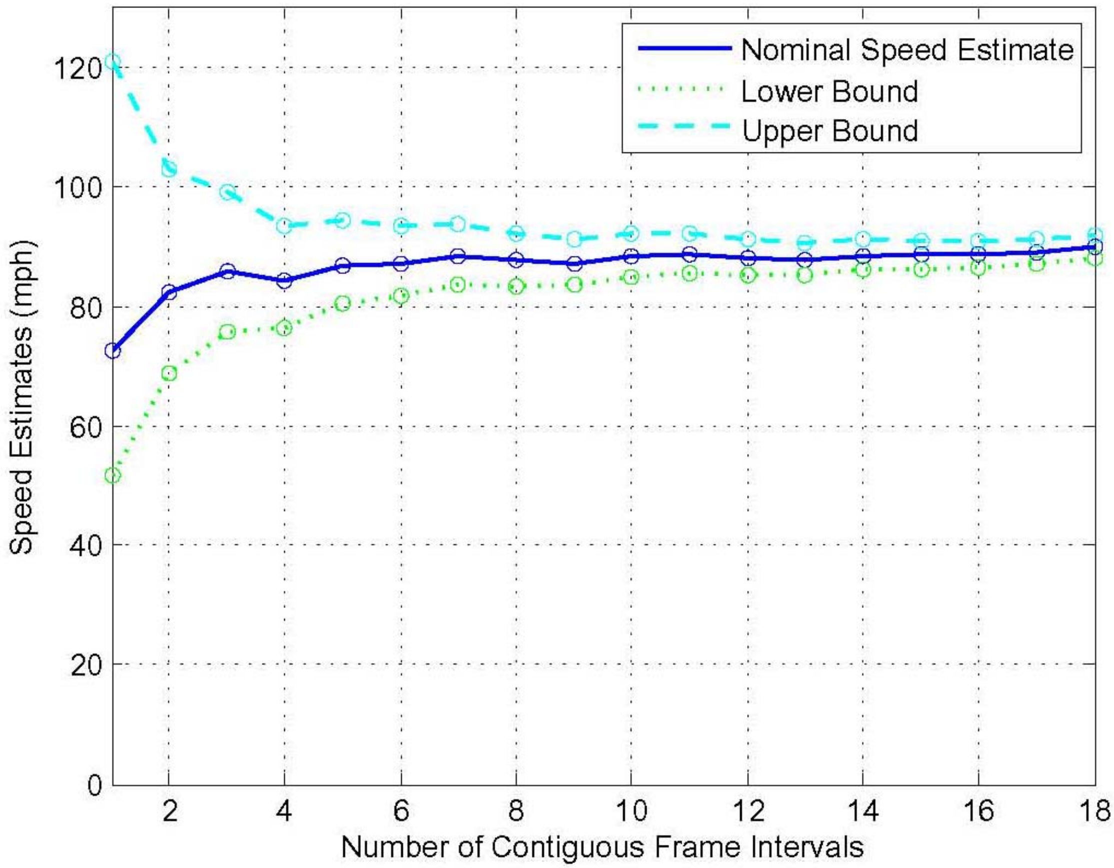

Figure 14. Vehicle speed estimate versus number of frame intervals (video analysis).

Vehicle Acceleration Analysis

Safety Board staff also conducted analytical work to determine whether the accident motorcoach could have reached the estimated speeds shown in figure 14 with the engine governed at 72 mph.[78] That analysis was based on the physical parameters of the vehicle (including mass, aerodynamic drag coefficient, and tire rolling resistance coefficient) and the forces acting on the vehicle.[79] The acceleration was estimated using a simulation model of the

[78] The accident motorcoach's engine had a governor that shut off fuel at 72 mph.

[79] Vehicle mass, frontal area of the vehicle, air density, downgrade slope, and acceleration of gravity were known with some degree of precision. The nominal value of the aerodynamic drag coefficient was estimated to be 0.6 and the values of 0.5, 0.6, and 0.7 were considered in the analysis. The nominal value of the tire rolling resistance coefficient is usually assumed to be 0.01, and the values of 0.01 and 0.02 were considered in the analysis.

vehicle dynamics starting with the motorcoach entering a 4.5-percent downgrade at 70 mph. That analysis showed the vehicle reaching a speed of 90 mph in 54 seconds.[80]

Over the 1,000-foot-long segment of roadway approaching the curve, the road downgrade decreases from about 5 percent to about 3 percent. An analysis was performed to estimate the effect of the downgrade reduction on the motorcoach's speed. That simulation started at 88 mph and showed the motorcoach to slow by less than 0.2 mph.

The Safety Board also calculated a terminal velocity of the vehicle, which is a steady state speed at which gravitational forces on the roadway downgrade are balanced by aerodynamic drag and tire rolling resistance forces. The nominal terminal velocity on a 5-percent downgrade using conservative values[81] was estimated to be 96.7 mph. Although these vehicle performance analyses are only estimates based on acceptable engineering practices, they serve as additional confirmation that the motorcoach could attain the 88-mph speed estimated from the video analysis.

Engine Performance Data

The motorcoach's engine ECM provided two data parameter fields within the Fleet and Driver Trip Reports that were used for evaluating the validity of the speed analyses. The subject ECM data indicated that the maximum vehicle speed ever obtained during the vehicle's life was 88 mph.[82]

Staff also conducted a vehicle speed-by-gear ratio analysis based on the accident motorcoach's known mechanical properties. Although the motorcoach's engine was governed at 72 mph, it was capable of achieving much higher road speeds while in 10th gear when going downhill. Calculations indicated that, while in 10th gear, the motorcoach could obtain a road speed of approximately 88 mph with the engine being driven at 2,000 rpm.

[80] Over a distance of approximately 6,500 feet.

[81] The analysis used an aerodynamic drag coefficient of 0.7 and a rolling resistance coefficient of 0.02.

[82] ECM values are not heavily filtered and can be subject to "noise" that generates "spikes" in the data received and interpreted by the ECM. Data spikes in vehicle speed can be the result of noise caused by excessive vibration, the improper installation of a speed sensor, or intermittent connections within the wiring.

Analysis

This analysis first discusses the factors and conditions that the Safety Board has excluded as neither causing nor contributing to the accident. It then provides a brief overview of accident events and discusses some of the safety issues relevant to the accident: driver fatigue, excessive vehicle speed, hours-of-service violations, and motor carrier trip planning. It then discusses the Safety Board's concern about the motorcoach crashworthiness and the lack of adequate occupant protection systems for passengers in commercial motorcoaches. The analysis concludes with a discussion of emergency medical services notification and response with regard to large motorcoaches traveling on rural roads.

Exclusions

Single-vehicle, run-off-the-road crashes are primarily associated with driver fatigue or distraction. Based on interviews and video records, the Safety Board was able to rule out several of the most common driver distractions. Video evidence also confirmed that the driver was not using his cellular telephone and was not incapacitated at the time of the accident. Toxicological testing found no evidence of illicit drugs. The Safety Board therefore concludes that the driver was neither distracted by his cellular telephone nor impaired by illicit drugs at the time of the accident. Although the Safety Board can conclude from toxicological testing that the driver was not impaired by illicit drugs, toxicological testing was performed too late for the Safety Board to conclusively rule out alcohol as a factor in this accident. However, there was no evidence that the driver drank during the 5 hours that he drove the bus; nor was there evidence for the police to have probable cause to test the accident driver for alcohol or drugs. The Safety Board therefore concludes that, although it was unlikely that the driver was under the influence of alcohol, the delay in collecting a toxicological specimen prevents the Safety Board from conclusively ruling out alcohol as a factor in this accident.

Although the weather affected the accident trip overall, road conditions at the time of the accident were reported to be dry. The Safety Board therefore concludes that the weather at the time of the accident was not a factor in the motorcoach's departure from the roadway. Based on physical evidence, investigators were also able to confirm that a tire blowout, brake failure, or steering failure did not affect the driver or vehicle. There were no precrash mechanical defects found during postaccident inspection of the motorcoach. The Safety Board concludes that the mechanical condition of the motorcoach was not a factor in this accident.

Investigators also considered the role of highway design in the accident. The accident curve's signage complied with the *Manual on Uniform Traffic Control Devices* (MUTCD).[83] The bank-ball indicator test conducted by UDOT confirmed that the curve did not need an additional

[83] U.S. Department of Transportation, Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (Washington, DC: FHWA, 2003).

advisory speed warning sign[84] for less than the 65-mph posted speed. Evaluation of the curve showed it had good frictional properties and the proper bank and radius for the posted speed. Additionally, no tire yaw marks were found on the roadway.[85]

The guardrail erected at the beginning of the curve provided a barrier for a drainage culvert at the bottom of a steep slope (1V:2H).[86] Although the absence of end treatment for the existing guardrail was substandard, it was not a factor in the accident. Following the guardrail in the center portion of the curve, the terrain rose into a 3-foot-high berm that would be traversable and might aid an errant motorist in regaining control after departing the roadway. The last section of the curve had a foreslope of 1V:3H that, according to the AASHTO *Roadside Design Guide*, is traversable but not recoverable. A longitudinal barrier or guardrail would not be warranted for a slope of this magnitude unless some other hazard was located on the slope in the clear zone.

In summary, the posted speed was appropriate for the curve, the signage was correct, and, based on *Roadway Design Guide* guidelines, additional roadside barriers were not warranted. The Safety Board concludes that the design and condition of the highway were not factors in this accident.

Accident Discussion

The part-time driver had been ill during his stay in Telluride, Colorado, and suffered from a self-reported difficulty sleeping that resulted in a lack of adequate rest during each of the 3 nights before the accident. He was experiencing head congestion that he attributed to a head cold, but the symptoms could also have been associated with altitude sickness.[87] Sleep disturbances are common in individuals sleeping at higher altitudes than normal and, on the first day of the trip, the driver gained 7,000 feet in altitude.[88]

The driver had previously been diagnosed with obstructive sleep apnea and was prescribed a CPAP device to assist with sleeping. The driver's head congestion would have resulted in restricted air capacity of his nasal passages, which, in turn, would have inhibited the effectiveness of the CPAP device, which operates by supplying forced air to assist in breathing. The driver did not use his CPAP device the first night in Telluride and used it only sporadically

[84] MUTCD, Sign W1-2.

[85] Tire yaw marks occur when a vehicle slides sideways while still moving forward.

[86] The slope dropped 1 foot vertically for every 2 feet of horizontal distance.

[87] Altitude sickness can occur when people rapidly ascend to a high altitude as a result of the combination of reduced air pressure and a lower concentration of oxygen at high altitude. Symptoms are commonly mild and can include difficulty sleeping, dizziness, fatigue, headache, nasal congestion, loss of appetite, nausea, rapid heart rate, or shortness of breath with exertion.

[88] T.A. Kinsman, A.G. Hahn, C.J. Gore, B.R. Wilsmore, D.T. Martin, and C.M. Chow, "Respiratory Events and Periodic Breathing in Cyclists Sleeping at 2,650-m Simulated Altitude," *Journal of Applied Physiology*, Volume 92, No. 5 (2002): 2114-8, determined that 15 of 17 subjects experienced significant increase in sleep-disturbing events at simulated altitudes of 2,000 to 8,700 feet.

the other 2 nights. Based on the driver's statements, he was aware that he had not been sleeping adequately during his time in Telluride. On the day of the accident, the driver had been awake for 8.5 hours, and, at 3:15 p.m., he began the anticipated 10–12 hour trip. Physical evidence of the vehicle's gradual departure from the road is consistent with run-off-the-road crashes associated with fatigue. The Safety Board therefore concludes that the driver was experiencing diminished alertness and fatigue-related impairment due to inadequate sleep resulting from the following factors: head congestion, possible problems acclimating to high altitude, and his sporadic use of his CPAP sleeping device during the accident trip.

Nine miles before the accident, at milepost 38, the driver would have experienced a sharp, well-marked curve where the posted speed decreased to 35 mph. Several interviewed passengers stated that before the accident, the driver drove off the road and when he swerved back, passengers' personal belongings slid out from under the seats.[89] At that point, a passenger shouted "slow down." Another passenger estimated this occurred about 10 minutes before the accident. That time estimate correlates with the sharp curve at milepost 38. Video evidence taken seconds before the accident also records a raised voice saying "slow down." Interviews indicate that passengers had voiced concern during the trip that the driver was going too fast.

The Safety Board's video analysis, summarized in the factual portion of this report and presented in detail in appendix C, determined that the vehicle was traveling at approximately 88 mph. The Safety Board conducted several other confirmatory estimates of speed. The ECM's recorded maximum speed for the accident motorcoach was 88 mph. Vehicle speed based on the DriveCam II video recorder's lateral accelerometer was estimated at 89 mph. Further, vehicle performance modeling of the vehicle's acceleration on the downgrade of the road and of its terminal velocity showed that the vehicle had the capacity to exceed 90 mph. Vehicle performance analysis using engine speed, gear ratios, and tire geometry also confirmed that the motorcoach could reach a speed of 88 mph. The Safety Board concludes that the motorcoach was traveling approximately 88 mph in a 65-mph speed zone when the driver departed the road and lost control of his vehicle.

Due to the driver's diminished state of alertness, he may have neglected to monitor the motorcoach's excessive speed as the vehicle traversed a long, straight descent. In a dark, rural area with few outside lights for reference and with some level of inside light reflection from the motorcoach's entertainment video, the driver may have focused exclusively on lane following on the narrow two-lane rural road.[90] The driver's lack of awareness of driving tasks was also evident in the route-following mistake that occurred shortly before the accident. The fact that a passenger had, within minutes of the accident, shouted for the driver to "slow down" makes a compelling case that the vehicle speed had been called to the driver's attention. At that time, several miles before the accident curve, the driver may have slowed down. But with the progressive downgrade, the motorcoach would have again picked up speed. A fatigued, inattentive driver may have been unaware of the increasing speed of the vehicle on the long downgrade just before

[89] A detection of lateral acceleration of 0.45 g would have started a 20-second video and data recording. The DriveCam II accelerometer did not record the reported event.

[90] C.D. Wickens, *Attentional Tunneling and Task Management*, NASA Ames Research Center Technical Report AHFD-05-23/NASA-05-10 (Moffett Field, CA: NASA, December 2005).

the accident curve. The Safety Board concludes that the driver's fatigue affected his monitoring of the motorcoach's speed.

The driver's excessive speed contributed to his inability to regain control of the vehicle once it departed the roadway. Reaction time for steering inputs to correct for the road departure would have been in the range of 2.5–4.0 seconds.[91] Evidence at the accident scene indicated that the vehicle traveled 350 feet from the point of road departure to where it lost traction on the embankment.[92] At a speed of approximately 88 mph, the vehicle would have traveled that distance in approximately 2.7 seconds.[93] The DriveCam II video recording shows that the driver traveled this portion of the accident sequence without reacting until the very end. Video evidence shows that the driver reacted more slowly than the passengers in realizing that the motorcoach had departed the roadway. The driver's abrupt final steering input to the left probably contributed to a vehicle trajectory that involved a full 360-degree rollover. The Safety Board concludes that the driver's reaction to the motorcoach's departure from the roadway was delayed and, by the time he executed corrective steering action, he had lost control of the vehicle.

The driver made a series of errors just before the accident that were associated with inattention: he was not monitoring his speed; he made some, but not enough, steering input to accomplish lane following; he did not respond to the increased lateral acceleration of the motorcoach;[94] and he was slower than the passengers in realizing that his right wheels were off the roadway. The accident sequence can therefore be summarized as follows: (1) the driver was fatigued and in a diminished state of alertness at the time of the accident; (2) the driver was speeding and neglected to establish an appropriate speed for the upcoming curve; (3) the driver's response to the road departure was delayed; and (4) given that delayed response, the driver had almost no opportunity to regain control of the vehicle.

Fatigue Countermeasures

The FHWA recommends that continuous shoulder rumble strips (CSRS) be installed on rural freeways and expressways as an effective means of reducing single-vehicle, run-off-road crashes caused primarily by motorist inattention. Utah is now installing these devices along its interstate highways as part of its HSIP. But, citing increased maintenance costs and safety concerns for bicyclists, the FHWA does not recommend CSRS for all roadway types. For rural

[91] National Cooperative Highway Research Program, *Human Factors Guidelines for Road Systems,* NCHRP Report 600A (Washington, DC: Transportation Research Board, 2008) uses 3 seconds in Perception-Identification-Emotion-Volition (PIEV) calculations and 2.5–4.0 seconds PIEV for brake reaction time. AASHTO uses 2.5 seconds for perception-reaction time (PRT) criteria. PRT should not be viewed as a fixed human attribute; therefore, a general range is most appropriate for this discussion.

[92] At 88 mph, the motorcoach could have traveled 323–516 feet in 2.5–4.0 seconds.

[93] Because the vehicle was decelerating based on the changing surface conditions, the time could be slightly longer.

[94] Research cited by AASHTO indicates that a lateral acceleration of 0.2 g or greater makes drivers uncomfortable, prompting them to slow down in response. The driver's lateral acceleration prior to departing the roadway, at 2.75 seconds before impact, reached 2.5 g, causing papers to slide off the front passenger seat.

multilane and two-lane roadways, the FHWA recommends that an engineering study or crash analysis be conducted to determine whether crashes would likely be reduced by the presence of rumble strips. The low traffic count and the low accident rate make it unlikely that the Utah DOT would embark on a CSRS infrastructure improvement along U.S. 163. Moreover, CSRS treatment to the roadside would not have prevented this accident because of the driver's excessive speed. The high-speed departure from a rural two-lane roadway with narrow shoulders offered too short a timeframe for detection, processing, and corrective action.

The Safety Board's recent investigation of a truck-tractor semitrailer rollover accident that resulted in the subsequent collision of a motorcoach with the overturned truck in Osseo, Wisconsin,[95] examined the issue of fatigue countermeasure technologies in detail. As a result of that investigation, the Safety Board asked that the FMCSA develop and implement a plan to deploy technologies in commercial vehicles to reduce the occurrence of fatigue-related accidents (Safety Recommendation H-08-13). The Safety Board is currently awaiting the FHWA's response to that recommendation.[96]

Driver Medical Conditions

In February 2007, the CDL medical examiner set the accident driver's fitness examination timeframe for renewal at 1 year instead of the usual 2 years due to the driver's hypertension.[97] During that examination, the driver did not acknowledge a history of sleep disorders. The driver's sleep disorder had been medically evaluated and was being treated with a CPAP device that the driver had used for approximately 1 month before the CDL medical examination. Because the driver's sleep disorder was being treated, it is unclear whether the medical examiner would have modified his certification decision even had that information been conveyed.

In addition to obstructive sleep apnea, the driver had a history of several other health conditions. His coronary artery disease had been treated, and a recent stress test was normal. His high blood pressure was controlled by medication. The driver was also obese; he had a body mass index (BMI) of 36.8 kg/m^2.[98,99] The FMCSA's Medical Review Board (MRB) has identified a set of medical conditions that, occurring in combination, would factor into the duration of medical certification. The investigation revealed that the driver had multiple medical conditions that are the subject of a recent MRB recommendation. However, no evidence exists,

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

[96] Safety Recommendation letter to the FMCSA dated February 2, 2009.

[97] Arrow also has an operating policy that states that drivers 65 years and older must be medically certified every year; Arrow pays for that medical certification.

[98] The Centers for Disease Control and Prevention defines obesity as a BMI of 30 kg/m^2 or greater.

[99] On January 28, 2008, the MRB presented recommendations to the FMCSA that included screening drivers for obstructive sleep apnea if they had a BMI of greater than 35 kg/m^2 and warning drivers of the consequences of CPAP device non-use.

either from the witnessed actions of the driver before the accident or from the driver's medical history, that these conditions played a role in the accident. The Safety Board therefore concludes that none of the driver's preexisting medical conditions, except for sleep apnea, played a role in this accident. The Safety Board is closely following the MRB's work and the FMCSA's disposition of its recommendations.

The Safety Board's Most Wanted List of Transportation Safety Improvements includes the prevention of medically unqualified drivers from operating commercial vehicles. Safety Recommendations H-01-17 through -24,[100] issued as a result of the Safety Board's investigation of a 1999 motorcoach accident in New Orleans, Louisiana,[101] address all aspects of an appropriate, comprehensive program for Federal medical oversight of commercial drivers.[102] In October 2008, the Safety Board considered this issue at its meeting to update the Federal Most Wanted List of Transportation Safety Improvements and classified the FMCSA's response on this issue as "Unacceptable." In February 2009, the Safety Board commented on the FMCSA's notice of proposed rulemaking (NPRM),[103] addressing the certification, training, and testing of medical examiners.

Hours of Service

Arrow received a conditional rating during a postaccident compliance review conducted in February 2008.[104] One component of that less-than-satisfactory rating was based on violations of the hours-of-service regulations (49 CFR Part 395). In addition to the accident driver, 16 other drivers associated with the Telluride trip had such violations: 14 had exceeded the 10-hour driving rule, 2 had falsified records, and 10 had exceeded the 15-hour work rule.

The lead driver communicated with Arrow management on the morning of the accident trip and, following that telephone call, made the decision to return to Phoenix along the alternate route. Hours-of-service regulations allow drivers to complete 10 hours of driving time under normal conditions. The regulations also provide consideration for adverse driving conditions, allowing for up to 12 hours of driving time, but only when those conditions are encountered en route, not if they are known prior to departure. The driving time exception would not have applied to the accident trip, which started on an alternate route because adverse weather had closed the preferred route, prompting drivers to begin the trip equipped with tire chains. The accident route was 556 miles, so travel time would have had to average better than 55 mph to not

[100] Only two of these eight recommendations (H-01-19 and -20, on updating medical certification regulations) are currently in "Acceptable" status.

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

[102] For more information, see <http://www.ntsb.gov/recs/mostwanted/medical_certification.htm>.

[103] Notice of Proposed Rulemaking, "National Registry of Certified Medical Examiners," *Federal Register*, vol. 73, no. 231, pp. 73129–73147.

[104] Arrow received two compliance reviews in the 2 years preceding the accident; in January 2006, Arrow received a satisfactory rating from the FMCSA; in October 2007, Arrow received a rating of 1 (highest) from the U.S. Department of Defense contractor Consolidated Safety Services.

exceed the 10-hour hours-of-service rule. Considering the mountainous secondary roads, adverse weather conditions, and time required to remove tire chains, the average rate of travel should have been expected to be less than 55 mph, resulting in a trip time that would have exceeded 10 hours. The Safety Board concludes that both Arrow and its drivers knew of the adverse weather conditions before starting the accident trip and thus intentionally engaged in a trip that would likely exceed hours-of-service regulations.

Until systemic monitoring capabilities are put in place, hours-of-service violations can be expected to continue. It has been the Safety Board's position that the only way the FMCSA can effectively enforce carrier hours-of-service compliance is to mandate the use of electronic on-board recorders (EOBRs) by all operators.[105] Over 2 years ago, the FMCSA issued an NPRM[106] requiring EOBRs for the most egregious hours-of-service violators; that NPRM has not yet been issued as a final rule. The Mexican Hat accident involves a carrier that would not likely be affected by the proposed EOBR rule; this accident again illustrates why the Safety Board's past recommendation called for EOBRs for *all* commercial operators, not just problem carriers. The Safety Board therefore reiterates its EOBR recommendation to the FMCSA:

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

Arrow Trip Scheduling

At the time of the accident, the driver had been driving for approximately 5 hours and was within the operational time constraints of the hours-of-service regulations. However, both Arrow and the drivers should have been aware that the scheduling of the longer return trip would be problematic. The trip route from Phoenix to Telluride was 486 miles, but the rerouted return trip was 556 miles, presenting the likelihood that contingency planning would be needed to avoid hours-of-service violations.[107]

Arrow's options to avoid exceeding hours-of-service requirements included overnight accommodations for the more than 800 passengers and drivers, either in Telluride or along the

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[105] As a result of its investigation of a 2004 accident involving a fatigued tractor-trailer driver, the Safety Board recommended that EOBRs be required for all interstate commercial carriers (Safety Recommendation H-07-41). For further information, read National Transportation Safety Board, *Rear-End Chain Reaction Collision, Interstate 94 East, Near Chelsea, Michigan, July 16, 2004,* Highway Accident Brief NTSB/HAB-07/01 (Washington, DC: NTSB, 2007).

[106] Notice of Proposed Rulemaking, "Electronic On-Board Recorders for Hours-of-Service Compliance," *Federal Register*, vol. 72, no. 11, pp. 2340–2394, January 18, 2007.

[107] FMCSA Regulation 392.6, *Schedules to Conform With Speed Limits*, provides the following guidance about trip length: Total trip distances of 550–600 miles on highways with a speed limit of 65 mph or of 450–500 miles on highways with a speed limit of 55 mph are considered "questionable," and motor carriers may be asked to document that such trips were made in compliance with the speed limit and hours-of-service limitations.

return route to Phoenix[108] or the provision of relief drivers along the route for the 17 motorcoaches. Either option would have required substantial coordination, both in terms of the logistics to arrange either hotel accommodations or additional drivers and with the charter passengers, who expected to return to regular activities on Monday following the weekend trip. Arrow could not reasonably expect the drivers to handle contingency plan arrangements for rescheduling the charter trip to avoid exceeding hours-of-service regulations. The Safety Board therefore concludes that Arrow should have developed contingency plans to avoid hours-of-service violations associated with the return trip.

For contingency plans to be effective, they must be considered before the start of the trip, documented, and coordinated with the charter group. The Safety Board believes that Arrow should develop written contingency plans for each charter to ensure that trip planning is in place in the event of driver fatigue, incapacitation, or illness or in the event of trip delays necessitating replacement drivers to avoid hours-of-service violations and inform drivers of their trip's contingency plans. Such plans could include but not be limited to: identifying alternate drivers and equipment and checking on their availability, identifying suitable relief positions to swap drivers or equipment, planning rerouting options around road closures or weather, and identifying overnight accommodations that could be contacted in the event that a trip needs to be delayed. Moreover, the Safety Board believes the American Bus Association (ABA) and the United Motorcoach Association (UMA) should inform their members through Web sites, newsletters, and conferences of the circumstances of the Mexican Hat, Utah, accident. The prepared information should encourage charter operators to develop written contingency plans for each charter to ensure that trip planning is in place in the event of driver fatigue, incapacitation, or illness or in the event of trip delays necessitating replacement drivers to avoid hours-of-service violations and inform drivers of their trip's contingency plans.

Occupant Protection Systems

A comprehensive occupant protection system considers many aspects of the vehicle, including roof strength, window glazing, seat strength, and restraints and their anchorage strength—all working together to protect occupants in the event of a crash. Further, the vehicle needs to remain intact and protect the survivable space of the occupants, and the occupants need to remain within their seating compartments.

The most direct method of retaining passengers in motorcoach seating compartments is lap/shoulder belts, but because no Federal regulations require motorcoaches in the United States to have occupant protection systems, few motorcoaches are so equipped. The Safety Board's 1999 bus crashworthiness special investigation[109] called for NHTSA to develop standards for motorcoach occupant protection systems and require their use. As a result of that special

[108] Arrow could have delayed the trip departure until the shorter route through Lizard Head Pass was reopened, though it is unlikely that room accommodations in the resort town would have been available. For such a large group, accommodations all along the return route would have been necessary.

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

investigation, the Safety Board issued recommendations concerning occupant protection and roof strength, two of which (H-99-47 and -50) are on the Safety Board's Most Wanted List of Transportation Safety Improvements:[110]

> In 2 years, develop performance standards for motorcoach occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers. (H-99-47)
>
> Once pertinent standards have been developed for motorcoach occupant protection systems, require newly manufactured motorcoaches to have an occupant crash protection system that meets the newly developed performance standards and retains passengers, including those in child safety restraint systems, within the seating compartment throughout the accident sequence for all accident scenarios. (H-99-48)
>
> In 2 years, develop performance standards for motorcoach roof strength that provide maximum survival space for all seating positions and that take into account current typical motorcoach window dimensions. (H-99-50)
>
> Once performance standards have been developed for motorcoach roof strength, require newly manufactured motorcoaches to meet those standards. (H-99-51)

The Safety Board's 1999 special investigation concluded that the overall injury risk to occupants in motorcoach accidents involving rollover and ejection would be reduced significantly by retaining the occupant in the seating compartment throughout the collision. Ten years later, no Federal regulations or standards require motorcoaches operated in the United States to be equipped with occupant protection systems except for the driver. This accident, with 50 ejections, represents an extreme case, but motorcoach passenger ejections during accidents are not rare. From 1998 to 2008, the Safety Board investigated 33 motorcoach accidents involving 255 passenger ejections (see appendix D).[111]

Complete separation of a motorcoach roof during rollover is a rare accident event that increases the likelihood of passenger ejections from the motorcoach. However, because energy increases exponentially with speed, the failure mechanisms affecting a vehicle traveling approximately 88 mph indicate little about the roof's ability to withstand controlled crash forces at significantly slower test speeds. Furthermore, because motorcoaches in the United States are not required to meet any roof strength standards, or even passenger crash protection standards, assessing the vehicle's ability to protect passengers during a crash at any speed is difficult.

[110] The Safety Board's Most Wanted List of Transportation Safety Improvements is a program to increase the public's awareness of and support for action to adopt safety steps that can help prevent accidents and save lives.

[111] The Safety Board is currently investigating six additional motorcoach accidents involving ejections: Westport, New York (HWY-06-MH-026); Clearfield, Pennsylvania (HWY-07-IH-020); Bowling Green, Kentucky (HWY-07-IH-022); Sherman, Texas (HWY-08-MH-022); Victoria, Texas (HWY-08-MH-011); and Dolan Springs, Arizona (HWY-09-MH-009). The total number of passenger ejections has not yet been determined.

Subsequent to issuance of the Board's safety recommendations, NHTSA developed a plan entitled "NHTSA's Approach to Motorcoach Safety."[112] NHTSA subsequently conducted frontal crash tests in December 2007 and rollover tests with instrumented dummies, both belted and unbelted, in February 2008, with the results of both sets of tests published in August 2008.[113] Vehicle and occupant instrumentation data, photographs, videos, and reports are currently being analyzed.

The Safety Board recognizes the extreme catastrophic nature of this particular rollover accident; however, what is at issue is not whether the crash forces exceeded the design standards, because no design standards currently exist for motorcoach roofs, seats, seat belts, or seat anchorages.[114] Although the Safety Board is encouraged that NHTSA is working toward developing standards by conducting tests, no changes can be anticipated until rulemaking occurs in this area. The Safety Board concludes that because of NHTSA's delay in defining motorcoach occupant protection performance standards, U.S. motorcoaches have not been equipped with such systems, leaving the traveling public inadequately protected during motorcoach crashes, particularly during rollovers. Because of NHTSA's unacceptably slow progress in defining and developing motorcoach occupant protection standards, the Safety Board is reclassifying Safety Recommendations H-99-47, -48, -50, and -51[115] from "Open—Acceptable Response" to "Open—Unacceptable Response."

Emergency Medical Services

Although the Safety Board recognizes that tour and charter bus accidents are relatively infrequent events,[116] it is their potential severity, not frequency, that is of concern. A tour or charter bus accident can be a mass casualty event that presents a challenge to any rural EMS operation. This section discusses (1) the delay in accident notification and potential improvements that could be made in that area; (2) the coordinated effort to handle 53 people, transported in 20 ambulances, to and through 13 different medical facilities spread across four

[112] Docket No. NHTSA-2007-28793.

[113] These tests used the following protocols for rollover protection strength and structural integrity: Federal Motor Vehicle Safety Standard (FMVSS) 220, School Bus Rollover Protection, and Economic Commission for Europe (ECE) Regulation 66, Uniform Provisions Concerning the Approval of Large Passenger Vehicles With Regard to the Strength of Their Superstructure.

[114] Motorcoaches must comply with FMVSS 217, which establishes standards for window retention and release. Motorcoaches do not have to comply with most FMVSS occupant protection standards applying to school buses and passenger cars.

[115] In the past decade, the Safety Board has reiterated these occupant protection recommendations in association with other accidents. Most recently, Safety Recommendations H-99-47 and -48 were reiterated in *Motorcoach Override of Elevated Exit Ramp, Interstate 75, Atlanta, Georgia, March 2, 2007,* Highway Accident Report NTSB/HAR-08/01 (Washington, DC: NTSB, 2008).

[116] To more accurately consider the safety risks of motorcoach operations, the Safety Board analyzed motorcoach accidents occurring from 2000 to 2007, affording the opportunity to include bus-use criteria. The analysis included all fatalities resulting from large bus accidents to capture the risk to all motorists and nonmotorists in crashes involving large buses (see appendix B). For the 8-year period, fatal accidents involving large buses totaled 1,093, for an average of 137 fatal accidents per year. Total fatalities for that timeframe totaled 1,315, for an average of 164 fatalities annually.

States and two sovereign Indian nations; and (3) the difficulty in understanding travel risk on rural roads used by tour and charter buses.

Emergency Notification

Effective management of traumatic injury is critically dependent on the time in which definitive care can be delivered.[117] It took 36 minutes to report the Mexican Hat accident, a delay that was directly attributable to a lack of wireless telephone coverage at the accident scene. According to the National Emergency Number Association and reported by the U.S. Government Accountability Office (GAO),[118] approximately 40 percent of all calls to 911 call centers, generically referred to as public safety answering points (PSAPs), are made on wireless telephones, and in some jurisdictions, that figure is higher.[119] According to the National Academy of Sciences, approximately 255 million wireless telephones are in use in the United States.[120] About 80 percent of Americans now subscribe to wireless telephone service; further, 14 percent of adults live in households with only wireless telephones (that is, no landline telephones). Yet, many rural areas, such as parts of San Juan County, do not have wireless telephone coverage,[121] and, in those areas, it is still not possible to make 911 calls from wireless devices.

Enhanced 911. A nationwide upgrade of 911 call systems, referred to as Enhanced 911 (E-911), is underway.[122] NHTSA issued an NPRM in October 2008 proposing that Federal grant funding be made available to enhance existing PSAP communication capabilities.[123] However, those monies cannot be used to establish wireless communication systems or to expand the coverage of existing systems, only to upgrade an existing system's infrastructure to handle digital Internet protocol (IP) service.[124] The E-911 initiative is an interagency program involving NHTSA and the National Telecommunications and Information Administration (NTIA) of the U.S. Department of Commerce. The initiative, managed by NHTSA's Office of Emergency Medical Services, will enable PSAPs to automatically receive location and call-back information

[117] It is widely accepted that a victim's chances of survival are greatest if definitive care is received in the operating room within the first hour after a severe injury.

[118] U.S. Government Accountability Office, *Telecommunication: States' Collection and Use of Funds for Wireless Enhanced 911 Services*, GAO-06-338 (Washington, DC: GAO, 2006).

[119] PSAPs receive 200 million calls annually; 82 million are wireless.

[120] *Emergency Medical Services: At the Crossroads.*

[121] Since the accident, three cellular antenna/repeaters have been installed near the accident site.

[122] Ensuring Needed Help Arrives Near Callers Employing 911 (ENHANCE 911) Act of 2004 (Public Law 108-494, codified as 47 *United States Code* [U.S.C.] 942). The Act authorizes grants for the implementation and operation of Phase II E-911 services and for migration to a voice-over Internet protocol, Internet protocol-enabled emergency network that provides caller identification and location information.

[123] Notice of Proposed Rulemaking, "E-911 Grant Program," *Federal Register*, vol. 73, no. 193, pp. 57567-57580.

[124] According to Section 3011 of the Deficit Reduction Act of 2005 (Public Law 109-171), Congress has authorized $43.5 million to NTIA for implementation of E-911.

associated with emergency calls. E-911 systems serve as the foundation for public emergency services in a wireless environment and are the basis for automatic crash notification systems.

In 2003, the GAO examined how States use revenue collected from fees on wireless customers' bills,[125] which wireless carriers pass on to States and localities to support 911 services.[126] During its investigations, the GAO found that States have often used these funds for other purposes. Concerns over misappropriation have influenced the restrictive nature of the E-911 grant process in which grants are to be used exclusively for IP infrastructure upgrades.[127] But, by focusing exclusively on 911 IP infrastructure upgrades, the Federal government is systematically ignoring rural areas of the United States that do not have even basic wireless service. The Safety Board concludes that basic wireless service capability is needed along high-risk rural roads and along rural roads frequently traveled by large buses to enable wireless telephone notification of accidents and emergencies.

EMS Federal Oversight. According to the National Academy of Sciences, "government leadership in emergency care is fragmented and inconsistent" with "a regulatory vacuum at the Federal level."[128] A host of departments, divisions, and agencies play a role in the various aspects of EMS: the Federal Communications Commission regulates carriers, State and local jurisdictions control PSAPs,[129] NTIA funds some infrastructure development, the U.S. Department of Homeland Security provides equipment grants,[130] and a Federal committee coordinates policy. In addition, many other agencies have a vested interest in emergency notification systems, including the U.S. Department of Health and Human Services, the Centers for Disease Control, the U.S. Department of Commerce, and FEMA.

The congressionally mandated Federal Interagency Committee on Emergency Medical Services (FICEMS) was established by the 2005 SAFETEA-LU legislation. The law required the Secretaries of Transportation, Health and Human Services, and Homeland Security to establish FICEMS and required NHTSA to provide administrative support. As a result, FICEMS was established to identify EMS services and 911 needs; ensure coordination among Federal, State, and local entities; and recommend new or expanded programs, such as E-911.[131]

A pervasive wireless capability throughout our nation's highway system will undoubtedly improve highway accident notification for EMS response and coordination of prehospital

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[125] Since 2003, the GAO has investigated other aspects of E-911. See U.S. Government Accountability Office, *Survey on State Wireless E911 Funds*, GAO-06-400SP (Washington, DC: GAO, 2006) and *Telecommunication: States' Collection and Use of Funds for Wireless Enhanced 911 Services* (GAO-06-338).

[126] GAO reported that these charges range from $0.20-3.00 per month per subscriber.

[127] As explained in the "Background" section of the E-911 NPRM.

[128] *Emergency Medical Services: At the Crossroads*, pp. 3 and 153, respectively.

[129] Organizationally, the approximately 6,000 PSAPs reside in fire, police, city, county, or other public health entities.

[130] Although EMS personnel represent a third of the nation's first responders, EMS providers receive only 4 percent of the funds distributed by the Department of Homeland Security for emergency preparedness.

[131] The first meeting of FICEMS was held on December 8, 2006, and the committee meets twice a year.

transport and offer substantial collateral benefit to rural citizens. Local public officials will be able to better monitor and respond in cases of fire, medical emergencies, hazardous material spills, and law enforcement activities. Further, cellular towers are often used to house autonomous weather stations that could assist with the dispatch of air medical assets and improve local sensor information of severe weather events. The Safety Board concludes that until wireless service capability is extended along highly traveled rural roads, motor carriers servicing rural areas without wireless telephone coverage remain at risk of being unable to report an accident or emergency in those locations. The Safety Board believes that FICEMS should develop a plan that can be used by the States and PSAPs to pursue funding for enhancements of wireless communications coverage that can facilitate prompt accident notification and emergency response along high-risk rural roads, as identified under SAFETEA-LU criteria, and along rural roads having substantial large bus traffic (as defined by the criteria established in Safety Recommendation H-09-07). These plans could include State HSIP projects to develop cellular communication for transportation accident notification. The Safety Board recognizes the amount of time that will be required to develop the infrastructure necessary for wireless communication along rural roads. In the interim, the Safety Board believes that the ABA and the UMA should inform its members through Web sites, newsletters, and conferences about the risks of operating in rural areas without wireless telephone coverage and advise members to carry mobile cellular amplifiers[132] or satellite-based devices[133] to communicate emergency events.

Emergency Response

The EMS community understands well the challenges faced by rural EMS. According to the National Academy of Sciences, the issues facing rural EMS include potentially lengthy response times; long travel distances to medical facilities; increased regionalization[134] of medical services, resulting in a loss of medical care facilities and emergency departments in rural areas; and a major shift to air ambulance services to overcome the long patient transport distances.[135] The Mexican Hat accident dramatically illustrates each of these issues.

Due to travel distances, the first emergency response unit arrived on scene almost an hour after the accident occurred, and the injured were transported from the scene for more than 4 hours following the accident. The limited local EMS resources and critical care facilities available in the Mexican Hat accident area dictated that assistance be drawn from around the region,[136] ultimately involving 13 medical facilities in four States (Utah, Arizona, New Mexico,

[132] Electronics designed specifically for mobile applications can be used to amplify weak cellular signals in rural areas. For example, Wilson Electronics in St. George, Utah, sells a mini-mobile amplifier kit that is comparable in cost to a GPS unit.

[133] Transport companies often make use of satellite-based mobile resource management systems. In addition to satellite phones, satellite personal trackers are available (for example SPOT Portable ELT) that provide real-time location tracking using Google Earth with one-way text messaging.

[134] *Regionalization* refers to the organization of a health care delivery system within a region to avoid the costly duplication of services.

[135] *Emergency Medical Services: At the Crossroads*.

[136] Utah has statutory requirements for intrastate and interstate mutual aid (Utah Code, Title 53, chapter 2, sections 201 and 501).

and Colorado). To transport the injured to these facilities, 20 ambulances and 3 general-purpose transport vehicles were used. A local mass casualty response trailer, one of nine positioned around the State, was driven to the accident site by the EMS Coordinator.[137] The morning after the accident, an EMS support team from Price, Utah, arrived to support EMS operations and relieve the local first responders who had worked through the night; that team traveled more than 4 hours to arrive at Monticello, Utah.

Only BLS ambulances with EMTs were available locally.[138] None of these ambulances were staffed with paramedics, causing ALS capability to be delayed because of travel distances. Seven ALS ambulances staffed with paramedics responded to transport patients between medical facilities, some in inclement weather, with two ambulances traveling 230 miles from Grand Junction, Colorado; three traveling 117 miles from Moab, Utah; and two traveling more than 60 miles from Cortez, Colorado. Triage operations were conducted at the closest hospital to the accident site, San Juan Hospital, in Monticello, Utah, 75 miles away,[139] and at a family clinic in Blanding, Utah, 40 miles away.[140] The nearest trauma center, St. Mary's Hospital, was approximately 230 miles from the accident site, in Grand Junction, Colorado. Several seriously injured passengers were driven from the accident scene a distance of 117 miles to Allen Memorial Hospital in Moab and then transferred to an EMS airplane and flown to a trauma center in Salt Lake City, Utah.

Two 16-year-old victims died after being transported from the accident scene. They received stabilization medical care at San Juan Hospital and from there were en route to hospitals with trauma treatment capabilities. One victim, en route to the Moab Airport to be airlifted to Salt Lake City, was diverted to Allen Memorial Hospital in Moab due to that victim's deteriorating medical condition. That victim died at 3:36 a.m., 7 hours after the accident. Another victim died just after reaching St. Mary's Hospital at 9:05 a.m. the next morning, 12.5 hours after the accident. Both had serious injuries, including head trauma.

One EMS solution to travel distances in rural areas is air medical response, because it can reduce transport time to emergency care and can provide a higher skill mix of medical flight crews. The growth of air medical response parallels hospital regionalization; further, the air medical industry is increasingly using EMS helicopters to bring more of the assets of a trauma center—including physician-level skills, hospital-type equipment, and advanced drugs—directly to the accident scene. Unfortunately, this accident highlights the obvious limitation of an emergency response system that relies on air transport. Weather grounded the two helicopters requested from Grand Junction and Phoenix, Arizona, thereby precluding rapid air EMS transport for the most severely injured.[141] Transfers to a fixed-wing air ambulance were made in

[137] The trailer contains BLS supplies, such as backboards and medical supplies, for 100 people.

[138] Although ALS-equipped ambulances were on scene, they lacked paramedics who could provide more than basic life support care.

[139] Twenty-six accident victims were transferred to San Juan Hospital by ground ambulances, rescue units, and county vans. Most were in serious condition, requiring stabilization and transfer to higher levels of care.

[140] Thirteen accident victims were transported to this clinic; several were then transferred to other facilities.

[141] By the afternoon after the accident, two helicopter crews were able to land in Blanding, Utah, to provide patient transport to higher-level care facilities.

Moab, Utah, because that airport had an instrument approach for IFR flight; these transfers required a 117-mile trip by ground ambulance from the accident scene. The Safety Board concludes that the regionalization of medical care relies on air medical support to accomplish timely long-distance patient transport without adequate contingency plans when air medical services are not available because of weather or equipment limitations.

The Safety Board acknowledges the efforts of the on-scene emergency response and the challenges that had to be overcome by the EMS responders. Many aspects of the Mexican Hat EMS response are to be commended. Although its timeliness was affected by travel distances, mutual aid response by surrounding jurisdictions appeared to be well coordinated. A mass casualty incident trailer was locally available and used by the EMS Coordinator on scene. Many volunteers supported the EMS first responders.[142] An EMS regional support team arrived from Price, Utah, the morning after the accident to relieve first responders who had worked through the night. Postaccident review meetings were conducted at the local hospital.

While the available regional resources were well utilized, emergency response would still have benefited from the availability of local paramedics with ALS ambulances and trauma centers closer to the accident site. The Safety Board recognizes that although these are desirable assets for any community, funding issues must be considered, particularly for a large, rural jurisdiction such as San Juan County. In most States, as with Utah, the State handles EMS licensing, training, and regulatory policy, while EMS operations, including grant writing and funding, are performed locally.[143] The Safety Board concludes that although the EMS mutual aid drawn from around the region was well coordinated, long-distance ground travel delayed the availability of ALS care. The Safety Board believes the Utah Bureau of Emergency Medical Services and its State Emergency Medical Services Committee should establish written contingency plans for response to large-scale transportation-related emergencies along rural roads traveled by tour and charter buses, such as occurred in Mexican Hat, Utah, that cannot be handled by air medical services due to inclement weather. Additionally, the Safety Board believes that FICEMS should evaluate the system of emergency care response to large-scale transportation-related rural accidents and, once that evaluation is completed, develop guidelines for EMS response and provide those guidelines to the States. The Safety Board realizes that the varied nature of State EMS organizations, as well as their characteristic differences, may dictate that several sets of recommended practices or guidelines be developed or that the information be developed in modules that can be customized by States.

Risk Assessment of Charter and Tour Bus Travel on Rural Roads

The Mexican Hat accident route, U.S. 163, highlights one of the difficulties in defining rural roads. Mexican Hat, Utah, is located in San Juan County, the largest county in the State,

[142] A passing motorist drove to the nearest town to report the accident. A second Arrow motorcoach driver stopped at the accident scene before first responders arrived. A passing truck provided temporary emergency lighting, and other motorists assisted the victims.

[143] *Emergency Medical Services: At the Crossroads* concluded that the States are often left to their own devices to develop EMS arrangements.

covering 7,933 square miles, making it larger than several eastern States. It is also sparsely populated, with fewer than two people per square mile. Although the ADT count along the accident route is quite low at 650 vehicles per day, the route connects several major tourist locations[144] that experience elevated levels of seasonal traffic, particularly commercial tours. ADT counts do not distinguish vehicle type and, because they represent an average, can disguise peaks in seasonal traffic.

The Safety Board's analysis of fatal accidents involving buses indicates that rural road travel risk extends to tour and charter buses (see appendix B).[145,146] The analysis determined that the risk of a fatal accident and subsequent injury to charter and tour bus occupants is greater in rural areas than in urban areas and that this pattern is consistent with the overall pattern in rural fatal accidents.[147]

The importance of rural road travel risk was underscored in the 2005 SAFETEA-LU legislation, which involves a set-aside allocation for high-risk rural roads, which States can use to fund HSIPs.[148] Underlying a State's development of a HSIP is the SAFETEA-LU requirement to incorporate a risk-based, data-driven, analytical approach to highway safety. This requirement is based on traditional approaches to risk assessment using accident frequency and accident severity. The analysis must include, at a minimum, use of crash data to identify hazardous locations and roadway elements, criteria for establishing the severity of locations, priorities for corrective action based on data analysis, and a data-driven means for evaluating the effectiveness of HSIPs.

Analysis based solely on fatal accidents and fatalities results in a focus on infrequent, worst-case scenarios. Fatal accidents typically account for less than 1 percent of the total number of accidents in any one year. In addition, an analysis that considers only fatalities cannot adequately account for accidents that produce a large number of nonfatally injured, such as motorcoach accidents, and the subsequent demands placed on emergency response systems.

[144] In the vicinity are the Valley of the Gods, Four Corners Monument, Arches National Park, Lake Powell, Mesa Verde National Park, Bryce Canyon National Park, Zion National Park, and Grand Canyon-Parashant National Monument.

[145] The data in appendix B are based on two data reports prepared in support of the Mexican Hat, Utah, accident investigation: *Large Bus Accidents and Injuries in Rural and Urban Areas, 2000–2006*, May 29, 2008, and *Addendum 1—Large Bus Accidents and Injuries in Rural and Urban Areas, 2000–2007*, December 31, 2008. Both the data report and data report addendum are available in the accident docket (HWY-08-MH-012).

[146] In addition to the FARS analysis presented in appendix B, the Safety Board conducted a study entitled *Study of Rural Travel Risk Factors for Large Buses: Fatal Accidents, Emergency Response, and Highway Safety Improvements.* The Safety Board's work is summarized in this section and included in its entirety in the Mexican Hat accident docket (HWY-08-MH-012).

[147] In fatal accidents involving charter/tour buses, the proportion of fatally injured occupants (24 percent) represented a substantially larger proportion of total fatalities in rural accidents than in urban accidents (3 percent). (See appendix B for more details.)

[148] Title 23 U.S.C. Section 148 was established by Section 1401 of SAFETEA-LU, which implemented HSIPs effective October 2005.Title 23 U.S.C. Section 148 establishes suballocations (set-asides) for two specific purposes: highway-rail grade crossings and high-risk rural roads.

VMT and ADT provide the standard measures of highway activity in the assessment of accident risk and, when used to calculate accident rates, are the basis for identifying road segments and locations that meet high-risk criteria. States collect VMT data and are required to use such data to assess risk in the development of an HSIP, but the detail is typically insufficient to determine the routes and travel characteristics of charter and tour buses. This is especially true in States such as Utah, where travel between population centers and recreation areas may include long distances through remote areas.[149]

Finally, the "ruralness" of a road differs substantially from one area of the country to another. The FHWA functionally classifies roads using a population census definition. In that classification, an "urban road" is defined as any road or street within the boundaries of an urban area with a population of 5,000 or more, and a "rural road" is any road not classified as urban. This classification based on population reasonably assumes that traffic volume in urban areas will be greater than in rural areas. However, it does not consider factors such as use or travel patterns or traffic corridors, nor does it adequately characterize the extent of long-distance travel in remote areas.

While the Safety Board supports data-driven decision-making for HSIP projects, programmatic measures that rely primarily on fatal accidents and aggregated activity data (such as VMT and ADT) cannot adequately characterize the accident risk of rural travel, especially in rural areas that may experience relatively high volumes of charter or tour bus traffic. The Safety Board concludes that the lack of adequate data on large bus travel in rural areas—especially data related to charter and tour bus activity, travel patterns, and routes—severely limits a State's ability to assess rural road travel and hazardous locations, especially in remote areas where a tour or charter bus accident can result in large numbers of injured.

HSIPs have historically focused on highway design features and infrastructure characteristics. This accident and the analysis of rural fatal accidents involving charter and tour buses indicate that the risks of rural road travel are not limited to highway design features but may also be associated with the consequences of a mass casualty event. A recent GAO report[150] found that the FHWA's emphasis on infrastructure projects in HSIPs may not allow States to allocate Federal safety dollars to their highest-priority safety improvements and specifically referred to EMS projects. The report concluded that Congressional action should be taken to modify the HSIP's flexible funding provisions so that States can more freely direct funds to EMS and other such projects.

Accident risk assessment in rural areas that experience high volumes of charter or tour bus travel can be used to target roads and road segments for special consideration. Moreover, an accurate assessment of all nonfatal injury accidents is necessary to evaluate emergency response

[149] Industry estimates are available, but they, too, contain aggregate data and insufficient detail to support detailed analyses of charter and tour bus routes and travel patterns. Furthermore, the source of the industry estimates and the validity of the methods used to obtain the data cannot be adequately verified.

[150] U.S. Government Accountability Office, *Highway Safety Improvement Program: Further Efforts Needed to Address Data Limitations and Better Align Funding with States' Top Safety Priorities*, GAO-09-35 (Washington, DC: GAO, 2008), pp. 5, 7, 14, and 31–33.

capabilities in rural areas. The accident data for rural accidents involving charter or tour buses, where almost all of the transported injured are bus occupants, show that these types of accidents can place substantial demands on rural EMS (see appendix B).

The Safety Board believes that the FHWA should develop and implement, in conjunction with AASHTO and the National Association of State EMS Officials, criteria based on traffic patterns, passenger volume, and bus types that can be used to assess the risks of rural travel by large buses. The Safety Board further believes that the FHWA should use this criteria as part of the SAFETEA-LU requirement to identify and select HSIP projects. The criteria should allow assessment of both fatal and nonfatal accidents involving large buses in all types of service and use, travel routes, travel activity and travel characteristics of these buses, and the potential problems for EMS in rural communities.

Conclusions

Findings

1. The driver was neither distracted by his cellular telephone nor impaired by illicit drugs at the time of the accident.

2. Although it was unlikely that the driver was under the influence of alcohol, the delay in collecting a toxicological specimen prevents the National Transportation Safety Board from conclusively ruling out alcohol as a factor in this accident.

3. The weather at the time of the accident was not a factor in the motorcoach's departure from the roadway.

4. Neither the mechanical condition of the motorcoach nor the design and condition of the highway were factors in this accident.

5. The driver was experiencing diminished alertness and fatigue-related impairment due to inadequate sleep resulting from the following factors: head congestion, possible problems acclimating to high altitude, and his sporadic use of his continuous positive airway pressure sleeping device during the accident trip.

6. The motorcoach was traveling approximately 88 mph in a 65-mph speed zone when the driver departed the road and lost control of his vehicle.

7. The driver's fatigue affected his monitoring of the motorcoach's speed.

8. The driver's reaction to the motorcoach's departure from the roadway was delayed and, by the time he executed corrective steering action, he had lost control of the vehicle.

9. None of the driver's preexisting medical conditions, except for sleep apnea, played a role in this accident.

10. Both Arrow Stage Lines and its drivers knew of the adverse weather conditions before starting the accident trip and thus intentionally engaged in a trip that would likely exceed hours-of-service regulations.

11. Arrow Stage Lines should have developed contingency plans to avoid hours-of-service violations associated with the return trip.

12. Because of the National Highway Traffic Safety Administration's delay in defining motorcoach occupant protection performance standards, U.S. motorcoaches have not been equipped with such systems, leaving the traveling public inadequately protected during motorcoach crashes, particularly during rollovers.

13. Basic wireless service capability is needed along high-risk rural roads and along rural roads frequently traveled by large buses to enable wireless telephone notification of accidents and emergencies.

14. Until wireless capability is extended along highly traveled rural roads, motor carriers servicing rural areas without wireless telephone coverage remain at risk of being unable to report an accident or emergency in those locations.

15. The regionalization of medical care relies on air medical support to accomplish timely long-distance patient transport without adequate contingency plans when air medical services are not available because of weather or equipment limitations.

16. Although the emergency medical service mutual aid drawn from around the region was well coordinated, long-distance ground travel delayed the availability of advanced life support care.

17. The lack of adequate data on large bus travel in rural areas—especially data related to charter and tour bus activity, travel patterns, and routes—severely limits a State's ability to assess rural road travel and hazardous locations, especially in remote areas where a tour or charter bus accident can result in large numbers of injured.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the driver's diminished alertness due to inadequate sleep resulting from a combination of head congestion, problems acclimating to high altitude, and his sporadic use of his continuous positive airway pressure sleeping device during the accident trip. The driver's state of fatigue affected his awareness of his vehicle's excessive speed and lane position on a downhill mountain grade of a rural secondary road. Contributing to the accident's severity was the lack of an adequate motorcoach occupant protection system, primarily due to the National Highway Traffic Safety Administration's delay in developing and promulgating standards to enhance the protection of motorcoach passengers.

Recommendations

New Recommendations

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

To the Federal Interagency Committee on Emergency Medical Services:

> Develop a plan that can be used by the States and public safety answering points to pursue funding for enhancements of wireless communications coverage that can facilitate prompt accident notification and emergency response along high-risk rural roads, as identified under SAFETEA-LU criteria, and along rural roads having substantial large bus traffic (as defined by the criteria established in Safety Recommendation H-09-7). (H-09-4)

> Evaluate the system of emergency care response to large-scale transportation-related rural accidents and, once that evaluation is completed, develop guidelines for emergency medical service response and provide those guidelines to the States. (H-09-5)

To the Utah Bureau of Emergency Medical Services:

> Establish written contingency plans for response to large-scale transportation-related emergencies along rural roads traveled by tour and charter buses, such as occurred in Mexican Hat, Utah, that cannot be handled by air medical services due to inclement weather. (H-09-6)

To the Federal Highway Administration:

> Develop and implement, in conjunction with the American Association of State Highway and Transportation Officials and the National Association of State Emergency Medical Services Officials, criteria based on traffic patterns, passenger volume, and bus types that can be used to assess the risks of rural travel by large buses. Use this criteria as part of the SAFETEA-LU requirement to identify and select Highway Safety Improvement Program projects. (H-09-7)

To the American Association of State Highway and Transportation Officials and the National Association of State Emergency Medical Services Officials:

Work with the Federal Highway Administration to develop and implement criteria based on traffic patterns, passenger volume, and bus types that can be used to assess the risks of rural travel by large buses. (H-09-8)

To the American Bus Association and the United Motorcoach Association:

Inform your members through Web sites, newsletters, and conferences of the circumstances of the Mexican Hat, Utah, accident. The prepared information should encourage charter operators to develop written contingency plans for each charter to ensure that trip planning is in place in the event of driver fatigue, incapacitation, or illness or in the event of trip delays necessitating replacement drivers to avoid hours-of-service violations and inform drivers of their trip's contingency plans. The prepared information should also provide information about the risks of operating in rural areas without wireless telephone coverage and advise members to carry mobile cellular amplifiers or satellite-based devices to communicate emergency events. (H-09-9)

To Arrow Stage Lines:

Develop written contingency plans for each charter to ensure that trip planning is in place in the event of driver fatigue, incapacitation, or illness or in the event of trip delays necessitating replacement drivers to avoid hours-of-service violations and inform drivers of their trip's contingency plans. (H-09-10)

Reiterated Recommendation

The National Transportation Safety Board reiterates the following recommendation:

To the Federal Motor Carrier Safety Administration:

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

Previously Issued Recommendations Classified in This Report

The following recommendations to the National Highway Traffic Safety Administration are classified "Open—Unacceptable Response":

> In 2 years, develop performance standards for motorcoach occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers. (H-99-47)
>
> Once pertinent standards have been developed for motorcoach occupant protection systems, require newly manufactured motorcoaches to have an occupant crash protection system that meets the newly developed performance standards and retains passengers, including those in child safety restraint systems, within the seating compartment throughout the accident sequence for all accident scenarios. (H-99-48)
>
> In 2 years, develop performance standards for motorcoach roof strength that provide maximum survival space for all seating positions and that take into account current typical motorcoach window dimensions. (H-99-50)
>
> Once performance standards have been developed for motorcoach roof strength, require newly manufactured motorcoaches to meet those standards. (H-99-51)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

KATHRYN O'LEARY HIGGINS
Member

DEBORAH A. P. HERSMAN
Member

ROBERT L. SUMWALT
Member

Adopted: April 21, 2009

Member Higgins filed the following concurring statement on April 28, 2009.

Board Member Statement

Member Higgins, concurring

I voted for and support the report on this accident. Important safety improvements were recommended and reiterated that, if implemented, will provide added protections for those who travel by motorcoach. I am pleased that we cited NHTSA in the probable cause as contributing to the severity of the accident, for their failure to formulate standards to protect motorcoach occupants. I am very disappointed, however, that the Board did not go further.

This accident should never have happened. The driver was fatigued before he got behind the wheel. While we cite his fatigue as the cause of the accident we did not place any responsibility on the company who planned the trip and employed the driver. I believe that we should have cited Busco Inc./dba Arrow Stage Lines in the probable cause of this accident. Busco/Arrow has been in business for 81 years, with business locations in 7 western states and the authority to operate in 48 states and Canada. Busco/Arrow operates 179 motorcoaches in scheduled and charter service with 337 drivers, including the 17 motorcoaches and drivers for the charter ski trip central to this accident. While this was the driver's first trip to Telluride, the company provided buses for this ski trip annually. This was the fifth such charter they arranged. They should have been familiar with the route, the weather, the change in altitude, the isolation of the region and the lack of cell phone service, and they should have planned accordingly. Busco/Arrow has a clear responsibility to plan for the unexpected—illness, bad weather, unforeseen emergencies, and anything else that could endanger the safety of their passengers. There was no contingency plan.

Management of this company knowingly approved a longer than normal return trip to Phoenix that would violate the hours-of-service limits for all the drivers. They made no provision to relieve drivers en route, apparently made no provision for drivers to be relieved for illness or fatigue—the driver complained that he'd been sick for three days—and made no provision for emergencies that <u>did</u> occur while their buses were transporting more than 800 passengers in a remote and isolated region in inclement weather. This company has the responsibility to recognize, anticipate, and prevent the consequences of driver behavior and environmental circumstances that put their passengers at risk. The driver bears primary responsibility for this accident, but I also believe the company is at fault.

Second, in our discussion during the Board Meeting, staff and I repeatedly agreed that this is a fatigue accident, not an hours-of-service accident. We did not agree, however, to include any recommendations related to fatigue in this report. I believe we should have asked Busco/Arrow to implement a fatigue management program for their employees. While they may provide information to their drivers on fatigue, they clearly have not done enough to make sure their drivers recognize the signs of fatigue and take the appropriate action. I appreciate the work FMCSA and others are doing in the area of fatigue management. However, I do not think we should have to wait for FMCSA to act before we ask Busco/Arrow to implement a fatigue management program. This accident clearly shows that motorcoach operators with good FMCSA ratings can still have fatigue accidents. We should have done more to address that issue by requiring this operator to establish a comprehensive fatigue management program to assist their drivers in recognizing the symptoms of fatigue and understanding the consequences of driving while fatigued.

Third, I understand the "rural" focus of the data recommendation for this report but I continue to be concerned that it will limit the development of exposure data and the evaluation of risk to rural areas. The special report prepared for this report (Appendix B) is very helpful in putting this accident in perspective. As staff emphasized during the Board meeting, data on motorcoach accidents is collected, but apparently very little is done with it. Given the increasing number of fatal motorcoach accidents, I believe we need an annual, comprehensive report that provides information on these accidents. Hopefully our recommendations will begin to generate information on accidents in rural areas, but I do not understand why we stop there. I believe one of the reasons there has been so little priority given to motorcoach safety is the lack of good, actionable information. The press, public, regulators and policymakers do not have the data in a form that would help them understand the dimensions of the problem. Motorcoach safety has been on our Most Wanted List for over a decade but we have seen very little movement on our recommendations. I believe we should recommend that DOT issue an annual report on motorcoach accidents that includes exposure data as well as data on injuries and fatalities, regardless of accident or travel location. Such information should be known and accessible to legislators, policymakers, regulators, investigators, and, most importantly, the traveling public.

Finally I urged that our long-standing recommendations on motorcoach occupant protection systems and electronic on-board recorders not only be reiterated to NHTSA and FMCSA but also be sent directly to the Secretary of Transportation. I believe it is important for the entire Board to be on the record in asking the new Secretary to make motorcoach safety a high priority. The agencies have not acted in 10 years. It will take the Secretary's leadership to change that track record. The Secretary is the only one who can hold his Administrators accountable. While I appreciate and welcome the acting Chairman's willingness to meet with the Secretary, I would have preferred a written request for action signed by all Board Members.

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Appendix A

Investigation

The National Transportation Safety Board was notified of the Mexican Hat accident on January 6, 2008. An investigative team was dispatched with members from the Washington, D.C.; Arlington, Texas; and Denver, Colorado, offices. Groups were established to investigate human performance; motor carrier operations; and highway, vehicle, and survival factors. No Board Member participated in the on-scene investigation.

Participating in the investigation were representatives of the Federal Motor Carrier Safety Administration, the Utah Highway Patrol, the Utah Department of Transportation, Arrow Stage Lines, and Motor Coach Industries. No public hearing was held, and no dispositions were taken.

Appendix B

Large Bus Accidents and Injuries in Rural and Urban Areas, 2000–2007[1]

Travel on rural roads has been recognized as especially hazardous. According to a recent National Highway Traffic Safety Administration (NHTSA) report that compared rural and urban accidents from 1994–2003, rural roads accounted for almost 60 percent of the fatal crashes and 60 percent of the fatalities, but only 39 percent of the total vehicle miles traveled (VMT).[2] During that period, 218,539 fatal rural road accidents occurred, resulting in 249,986 fatalities.

In support of the Mexican Hat accident, which occurred in a rural area, the Safety Board prepared a data report focusing on charter/tour bus travel on rural roads using fatal accident data from NHTSA's Fatality Analysis Reporting System (FARS) to determine the scope of charter/tour bus accidents in rural areas. The report examined fatal accidents involving large buses engaged in charter and tour operations, scheduled service, commuter service, and shuttle bus service from 2000–2007, using these data to show:

- Differences between rural and urban charter/tour bus accidents,
- Extent of fatal accidents involving charter/tour buses in rural areas,
- Fatalities and injuries for both bus occupants and occupants of other vehicles, and
- Number of injured transported to hospitals.

Data Limitations and Constraints

Accidents in FARS

Accident data drawn from the FARS database[3] provide a census of all fatal crashes within the United States, including the District of Columbia and Puerto Rico. A fatal crash is included in FARS if it involves "a motor vehicle traveling on a traffic way customarily open to the public, and must result in the death of a person (occupant of a vehicle or a nonmotorist) within 30 days of the

[1] The data in this appendix are based on two data reports prepared in support of the Mexican Hat, Utah, accident investigation: *Large Bus Accidents and Injuries in Rural and Urban Areas, 2000–2006*, May 29, 2008, and *Addendum 1—Large Bus Accidents and Injuries in Rural and Urban Areas, 2000–2007*, December 31, 2008. Both the data report and data report addendum are available in the accident docket (HWY-08-MH-012).

[2] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Contrasting Rural and Urban Fatal Crashes, 1994–2003*, DOT HS 809 896 (Washington, DC: NHTSA, 2005).

[3] For the latest data, from calendar year 2007, see <http://www-fars.nhtsa.dot.gov/Main/index.aspx>.

crash."[4] FARS has documented fatal highway crashes since 1975 and provides data for each crash in terms of accident event characteristics, the people and vehicles involved, and the extent and type of injuries suffered by vehicle occupants and nonmotorists. Data in FARS are based on State police accident reports and verified by FARS analysts.

Although FARS provides a census of all fatal highway accidents for any given year back to 1975, it represents only a very small subset of all accidents. For example, in 2007, 37,248 fatal accidents were represented in FARs, less than 1 percent of all accidents that occurred in that year.[5] As a result, large bus accidents involving injuries, but no fatalities, are not included in FARS or in the Safety Board's analysis.

Although fatal accidents can be viewed as the worst-case scenario, where the severity of the crash is sufficient to produce fatal injuries, they may not adequately characterize the kinds of accidents where nonfatal, but severe, injuries can occur. An accurate estimate of these types of accidents would be needed to adequately assess many of the risks of rural road travel (for example, the demands placed on emergency medical response).

The extent of the risk of injury during rural travel cannot be fully determined using only FARS data. In addition, fatal rural accidents involving large buses represent a small proportion of all fatal rural accidents. Given that almost 60 percent of all fatal accidents occur on rural roads, the magnitude of rural road travel risk may be substantially higher than is shown in this report.

Charter/Tour Bus Activity in Rural Areas

The calculation of accident rates to characterize accident risk is dependent upon accurate measures of activity, such as VMT or passenger populations, which are used as the basis for exposure measures to risk. These measures of exposure are used by Federal and State highway agencies in safety programs to calculate accident rates, evaluate accident risk, and help pinpoint areas of high risk on highways.

Accident rates are missing from this data report because accurate estimates of large bus activity are not readily available or reported. This is especially true for charter/tour bus operations in rural areas where travel patterns, travel characteristics, driver and passenger demographics, and seasonal variations are unknown. For example, the charter/tour bus involved in this accident was 1 of 17 buses traveling between a population center to a recreational area. Whether this was a rare, single trip or a regularly occurring trip is unknown, and the frequency with which the route is taken by such buses cannot be easily determined.

[4] U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, *FARS Analytic Reference Guide 1975–2006* (Washington, DC: DOT, 2006), p. F-i.

[5] For fatal crash data, see U.S. Department of Transportation, Bureau of Transportation Statistics, Table 2-27: *Motor Vehicle Safety Data* <www.bts.gov/publications/national_transportation_statistics/> and U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety Facts: 2007 Data*, DOT-HS-810-993 (Washington, DC: NHTSA, 2008).

Industry estimates of the number of passengers carried by buses exist, but these estimates are typically aggregated and contain insufficient detail to support the kinds of analyses found in this report. Furthermore, the source estimates and the validity of the methods used to obtain the underlying data cannot be adequately determined. This is especially problematic for assessing the risks of rural road travel because there do not appear to be any data collected on large bus travel in rural areas, especially in those areas where accident notification and emergency response might be an issue.

Accident Selection

As noted earlier, fatal accidents involving large buses were selected from FARS for the period 2000–2007. This timeframe was chosen because, prior to 2000, bus use was not universally recorded, and any analysis of bus activity relied on existing FARS criteria. As a result, before 2000, finding accidents involving buses of any type being used in a tour or charter would have been difficult.

The data report's analysis specifically uses FARS criteria related to bus use, bus body type, gross vehicle weight rating (GVWR), and vehicle configuration.[6] The analysis also characterizes buses as motorcoaches, transit/city buses, and large buses with a GVWR between 10,000 and 26,000 pounds. These distinctions allowed comparisons among buses of different types that may be used in a similar way. For example, both motorcoaches and smaller truck chassis-based tour buses may be used for tours and charters, which is also the case for buses used in shuttle service. In addition, transit/city buses are specifically designed for use in urban areas requiring slow speeds and frequent stops, and accommodating both seated and standing passengers. Further, because the Safety Board's analysis focused on accidents involving large buses being used in scheduled service, commuter service, or as a charter/tour or shuttle, vehicles in selected accidents had to meet the following criteria:

- Possess a "bus" body type,
- Be used in scheduled service, commuter service, or as a charter/tour or shuttle,
- Have a GVWR greater than 10,000 pounds, and
- Be configured to hold more than 15 passengers.

These criteria excluded school buses, other buses being used as school buses, and 15-passenger vans. (For more specific details about motorcoach selection criteria, see the reference section at the end of this appendix.)

[6] See the 2007 *FARS Coding and Validation Manual* for more details.

Finally, injury data were compiled for all of the fatal accidents cited in this report to show the extent of injuries in fatal accidents involving large buses so as to illustrate the need for accident notification and emergency medical services. Consequently, fatal and nonfatal injury data, and data indicating transport to a hospital, are shown for both bus occupants and occupants of the other vehicles involved in the accidents included in the data report.

Results Overview

Fatal accidents involving large buses in 2000–2007 numbered 1,093, resulting in 1,315 fatalities and 3,471 nonfatal injuries. Fatal accidents involving charter/tour buses accounted for 234 of the accidents (representing 21 percent of the total), resulting in 349 fatalities and 1,771 nonfatal injuries. The discussion that follows examines these accidents and injuries in more detail, specifically focusing on comparisons between rural and urban accidents.

Fatal accidents involving large buses (table B-1) occurred primarily in urban areas (table B-2). The 839 urban fatal accidents (table B-2) resulted in 950 fatalities and 1,808 nonfatal injuries (table B-3), accounting for 77 percent of the fatal accidents, 72 percent of the fatalities, and 52 percent of the nonfatal injuries.

Table B-1. Fatal accidents involving large buses, 2000–2007.

Bus use	2000	2001	2002	2003	2004	2005	2006	2007	Total
Charter/tour	27	33	30	20	37	36	19	32	234
Scheduled service	110	80	73	82	65	57	80	78	625
Commuter	21	28	21	22	14	22	30	20	178
Shuttle	6	5	9	7	8	10	2	9	56
Total	164	146	133	131	124	125	131	139	1,093

Table B-2. Fatal bus accidents by rural or urban location and type of bus, 2000-2007.

Bus type	Rural	Urban
Charter/tour		
Motorcoach	104	96
Transit/city bus	5	13
GVWR 10,000–26,000 pounds	5	3
Scheduled service		
Motorcoach	18	57
Transit/city bus	40	486
GVWR 10,000–26,000 pounds	1	5
Commuter service		
Motorcoach	4	11
Transit/city bus	18	132
GVWR 10,000–26,000 pounds	3	5
Shuttle service		
Motorcoach	10	14
Transit/city bus	3	6
GVWR 10,000–26,000 pounds	8	11
Total	219	839

Table B-3. Fatal and nonfatal injuries in fatal accidents involving large buses, 2000–2007.

All accident victims	Total[A]	Rural	Urban
Fatalities			
Charter/tour	349	195	148
Scheduled service	661	69	581
Commuter	206	45	160
Shuttle	99	37	61
Total	1,315	346	950
Nonfatal Injuries			
Charter/tour	1,771	1,172	586
Scheduled service	1,187	248	908
Commuter	246	100	145
Shuttle	267	97	169
Total	3,471	1,617	1,808
Total fatalities and injuries	4,786	1,963	2,758
Uninjured			
Charter/tour	343	177	161
Scheduled service	592	47	534
Commuter	173	23	146
Shuttle	51	20	31
Total uninjured	1,159	267	872

[A] Total includes accidents excluded from the Safety Board's analysis because they had unknown variables preventing them from being classified as either urban or rural. For more information, see table B-7 and its discussion.

Accidents involving buses in scheduled service accounted for the majority (65 percent) of the urban accidents, followed by buses in commuter service (18 percent), charter/tour buses (13 percent), and shuttle buses (4 percent). Almost all of the scheduled service bus accidents (88 percent) occurred in urban areas, and almost all of these types of urban accidents (89 percent) involved transit buses. The large number of urban accidents involving buses in scheduled and in commuter service reflects the high level of public transport provided by buses in populated areas.

In rural areas, charter/tour buses, rather than scheduled service buses, accounted for the greatest proportion of accidents. Charter/tour buses were involved in more than half (52 percent) of fatal rural accidents, with the remaining accidents divided among scheduled service (27 percent), commuter service (11 percent), and shuttle bus service (10 percent). Motorcoaches were involved in more than 60 percent of rural accidents; almost all of these motorcoaches were part of charters or tours.

These data show that rural fatal accidents involving large buses primarily involve motorcoaches being used in a tour or as a charter. This result is in contrast to urban accidents, which are dominated by transit/city buses in scheduled service.

Fatalities and Injuries

All Fatalities and Injuries

Fatalities and injuries resulting from the fatal accidents involving large buses are shown in table B-3. As might be expected, the large number of urban accidents produced the greatest number of fatalities and nonfatal injuries. However, nonfatal injuries were more evenly distributed between urban and rural accidents.

In urban areas, 950 fatalities and 1,808 nonfatal injuries occurred in fatal accidents involving large buses. Accidents involving buses in scheduled service accounted for 61 percent of the urban fatalities and 50 percent of the nonfatal injuries.

In rural areas, 346 fatalities and 1,617 nonfatal injuries occurred. Rural fatal accidents involving charter/tour buses accounted for 56 percent of the rural fatalities and 72 percent of the nonfatal injuries. Rural charter/tour bus fatal accidents resulted in more fatalities and nonfatal injuries than urban charter/tour bus accidents, a pattern that is exactly the reverse for accidents involving buses in any other type of service or use. In fact, rural accidents involving charter/tour buses resulted in almost twice the number of nonfatal injuries as urban accidents for the same bus type.

Bus Occupants

Overall, bus occupants accounted for a small percentage (15 percent) of the total number of fatalities in fatal accidents involving large buses (table B-4). However, a greater number of bus occupants were fatally injured in rural accidents than in urban accidents, with these fatalities accounting for more than a third of the total number of people killed in rural accidents. In contrast, bus occupants accounted for only 8 percent of the fatalities in urban accidents. The proportion of charter/tour bus occupants fatally injured in rural accidents (24 percent) represented a substantially larger proportion of the total number of rural fatalities than did the urban charter/tour bus occupants fatally injured in urban accidents (3 percent).

Table B-4. Bus occupant fatalities and nonfatal injuries in fatal accidents involving large buses, 2000–2007.

Bus occupant	Total[A]	Rural	Urban
Fatalities			
Charter/tour	111	82	29
Scheduled service	18	8	10
Commuter	10	8	2
Shuttle	58	22	36
Total	197	120	77
Nonfatal Injuries			
Charter/tour	1,572	1,061	502
Scheduled service	868	201	645
Commuter	195	89	106
Shuttle	234	84	149
Total	2,869	1,435	1,402
Total fatalities and injuries	3,066	1,555	1,479
Uninjured			
Charter/tour	172	61	108
Scheduled service	470	34	427
Commuter	144	18	125
Shuttle	37	12	25
Total uninjured	823	125	685

[A] Total includes accidents excluded from the Safety Board's analysis because they had unknown variables preventing them from being classified as either urban or rural. For more information, see table B-7 and its discussion.

Furthermore, bus occupants were more likely to be nonfatally than fatally injured in these accidents involving large buses. Bus occupants accounted for 89 percent of the nonfatal injuries in rural accidents and 78 percent of the nonfatal injuries in urban accidents.

Rural accidents involving charter/tour buses accounted for the largest proportion of all rural nonfatal injuries (72 percent). In fact, almost all (91 percent) of the nonfatal injuries in these rural charter/tour bus accidents occurred on the bus. Furthermore, rural fatal accidents involving charter/tour buses accounted for only 10 percent of the total number of fatal accidents involving large buses, but they resulted in 15 percent of the total fatalities and 34 percent of the total nonfatal injuries. In addition, passengers of buses involved in rural fatal accidents were less likely to escape injury than their urban counterparts; only 7 percent of bus occupants in rural accidents were reported uninjured, whereas 29 percent of bus occupants in urban areas were uninjured.

Injured Transported to Hospitals

The demands placed on emergency medical response and services can be estimated by the number injured in an accident who were transported to a hospital. FARS provides hospital transport data for all injured and indicates whether the injured person was an occupant of the bus. Almost 75 percent of all the people injured in fatal accidents involving large buses were transported to a hospital (table B-5). This was the case for both rural and urban areas.

Table B-5. Total injured transported to hospitals, 2000–2007.

Total injured transported to hospitals	Total[A]	Rural	Urban
Fatalities			
Charter/tour	114	50	63
Scheduled service	409	22	378
Commuter	107	11	95
Shuttle	27	7	19
Total	657	90	555
Nonfatal injuries			
Charter/tour	1,492	986	499
Scheduled service	892	175	705
Commuter	201	83	117
Shuttle	209	89	119
Total	2,794	1,333	1,440
Total transported	3,451	1,423	1,995

[A] Total includes accidents excluded from the Safety Board's analysis because they had unknown variables preventing them from being classified as either urban or rural. For more information, see table B-7 and its discussion.

As might be expected, a greater proportion of the nonfatally injured were transported to hospitals (81 percent) than the fatally injured (50 percent). In rural areas, a much smaller proportion of the fatally injured (26 percent) were transported, perhaps reflecting the greater severity of rural accidents and the greater emergency medical response times in rural areas.

For all accidents, a large proportion of the injured who were transported to hospitals (67 percent) were bus occupants (table B-6). In rural fatal accidents involving large buses, most of the transported injured were bus occupants (84 percent). In urban accidents, a much smaller proportion of the transported injured were bus occupants (55 percent). When only rural accidents involving charter/tour buses were considered, bus occupants accounted for almost all (88 percent) of the accident victims transported to a hospital. Almost all (98 percent) of these bus occupant transports had suffered nonfatal injuries.

Table B-6. Injured bus occupants transported to hospitals, 2000–2007.

Bus occupants transported to hospitals	Total[A]	Rural	Urban
Fatalities			
Charter/tour	19	14	5
Scheduled service	9	2	7
Commuter	3	1	2
Shuttle	8	4	4
Total	39	21	18
Nonfatal injuries			
Charter/tour	1,328	895	430
Scheduled service	605	132	470
Commuter	152	72	80
Shuttle	178	78	99
Total	2,263	1,177	1,079
Total transported	2,302	1,198	1,097

[A] Total includes accidents excluded from the Safety Board's analysis because they had unknown variables preventing them from being classified as either urban or rural. For more information, see table B-7 and its discussion.

Summary

Motorcoaches being used as a charter or in a tour account for most rural fatal accidents involving large buses. Overall, rural fatal accidents involving charter/tour buses accounted for only 10 percent of the total number of fatal accidents involving large buses, but they resulted in 15 percent of the total fatalities and 34 percent of the total nonfatal injuries. Charter/tour buses were involved in more than half (52 percent) of the fatal rural accidents, with the remaining bus accidents divided among scheduled service (27 percent), commuter service (11 percent), and shuttle bus service (10 percent). This result is in contrast to urban accidents, which are dominated by transit/city buses in scheduled service.

Rural fatal accidents involving charter/tour buses accounted for more than half of the rural fatalities and almost three-quarters of the rural nonfatal injuries, with almost all of the nonfatal injuries suffered by the occupants of the bus. The proportion of charter/tour bus occupants fatally injured in rural accidents was also substantially higher (24 percent) than the charter/tour bus occupants fatally injured in urban accidents (3 percent). Furthermore, passengers of buses involved in rural fatal accidents were less likely to escape injury than their urban counterparts.

The number of persons transported to hospitals was used as an estimate of the demands placed on rural emergency response. The data showed that, in rural accidents involving large buses, most of the people transported to hospitals were bus occupants. When only those accidents involving charter/tour buses were considered, almost all of the transported accident victims were bus occupants.

Reference

FARS Codes and Definitions

The FARS database is organized into three principal files: accident, vehicle, and person. Each of these files contains variables that code the characteristics of a fatal crash (called a *case*). In this analysis, all three files were used. Variables from each of these files were used in the Safety Board's data report; their respective codes and definitions are shown in table B-7.

Table B-7. FARS variables, codes, and code definitions.

Variable	FARS variable name	FARS codes used in analysis and definitions
Accident file		
Year	YEAR	2000–2007
Fatalities	FATAL	Count of total fatalities in an accident
Roadway function class (using Federal Highway Administration [FHWA] classification guidelines)	ROAD_FNC	01–Rural Principal Arterial—Interstate 02–Rural Principal Arterial—Other 03–Rural Minor Arterial 04–Rural Major Collector 05–Rural Minor Collector 06–Rural Local Road or Street 09–Rural Unknown 11–Urban Principal Arterial–Interstate 12–Urban Principal Arterial–Other Freeways or Expressways 13–Urban Principal Arterial 14–Urban Minor Arterial 15–Urban Collector 16–Urban Local Road or Street 19–Urban Unknown
Vehicle file		
How bus used in transport	BUS_USE	4–Used as Scheduled Service Bus 5–Used as Tour Bus 6–Used as Commuter Bus 7–Used as Shuttle Bus
Bus body type	BODY_TYP	51–Cross-Country/Intercity Bus (i.e.,Greyhound) 52–Transit Bus (city bus) 58–Other Bus Type 59–Unknown Bus Type
GVWR (maximum allowable total weight of bus, including weight of vehicle plus fuel, passengers, and cargo)	GVWR	2–10,000–26,000 pounds 3–26,000 pounds or more
Vehicle configuration	V_CONFIG	21–Bus (seats for more than 15 people, including driver)
Person file		
Vehicle body type occupied by injured and uninjured persons		51–Cross-Country/Intercity Bus (i.e., Greyhound) 52–Transit Bus (City Bus) 58–Other Bus Type 59–Unknown Bus Type
Severity of injuries	INJ_SEV	0–No Injury (O) 1–Possible Injury (C) 2–Nonincapacitating Evident Injury (B) 3–Incapacity Injury (A) 4–Fatal Injury (K) 5–Injured, Severity Unknown
Person type in accident	PER_TYP	01–Driver 02–Passenger of Motor Vehicle in Transport 03–Occupant of Motor Vehicle Not in Transport

Variable	FARS variable name	FARS codes used in analysis and definitions
		04–Occupant of Non-Motor-Vehicle Transport Device 05–Pedestrian 06–Bicyclist 07–Other Cyclist 08–Other Pedestrian (includes persons on personal conveyances) 09–Unknown Occupant Type in Motor Vehicle in Transport 19–Unknown Type of Nonmotorist
Transported to hospital	HOSPITAL	*For year 2007:* 0–No 1–Yes, EMS 2–Yes, Law Enforcement 3–Yes, Other 4–Yes, Transported by Unknown Source 9–Unknown *For years 2001–2006:* 0–No 1–Yes *For year 2000:* 0–No 1–Yes 7–Died at the Scene 8–Died En Route

Note that only those accidents meeting the specific criteria shown in table B–7 were included in the data study. Almost all the variables in the table have an “unknown” code; consequently, in any analysis where an unknown was possible in a critical variable, the case was excluded from the analysis. For example, in 16 of the 1,093 fatal accidents involving large buses, the variable roadway function class was coded “Unknown.” As a result, these 16 accident cases were excluded from any analysis that compared rural and urban accidents.

Motorcoach Selection Criteria for Data Study

The basic steps used to select specific accidents, types of buses, and bus occupants are described below.

Step 1: Select the time period for the accidents. As previously discussed, calendar years 2000–2007 were chosen for this analysis because one of the important variables, bus use, was not universally coded before 2000.

Step 2: Select fatal accidents involving large buses. Because accidents involving large buses being used in scheduled service, commuter service, or as a charter/tour or shuttle bus were being analyzed, vehicles in selected accidents had to meet the following criteria:

a. Possess a bus body type (FARS Body Type code of 51, 52, 58, or 59).

b. Be used in scheduled or commuter service, or as a charter/tour or shuttle bus. The set of accidents involving buses was further limited to those that met FARS BUS_USE codes equal to 4, 5, 6, or 7. These codes excluded any type of bus being used as a school bus.

c. Have a GVWR greater than 10,000 pounds. The set of accidents involving large buses being used in scheduled or commuter service or as a charter/tour or shuttle bus was further restricted to vehicles with a FARS GVWR code of 2 or 3.

d. Be configured to hold more than 15 passengers. This criterion required that all the fatal accidents in the final set equal FARS V_CONFIG code 21.

These criteria excluded school buses, any type of bus being used as a school bus, and small passenger vans configured to carry 15 or fewer passengers.

Step 3: Identify different types of buses. In the analysis, buses were characterized as motorcoaches, transit/city buses, and large buses with a GVWR between 10,000 and 26,000 pounds to allow comparisons among buses of different types that may be used in a similar way. Therefore, vehicles in selected accidents had to meet the following criteria:

a. Transit/city buses that were in the final set of fatal accidents derived from steps 1 and 2 were identified by the FARS BODY_TYP code 52 (Transit/City Bus).

b. Large buses with a GVWR between 10,000 and 26,000 pounds were identified by the FARS GVWR code 2.

Identifying motorcoaches required multiple criteria. As previously discussed, no FARS or NHTSA regulation definition of a motorcoach exists. In previous analyses of motorcoach[7] accidents, motorcoaches were treated as cross-country/intercity buses because such buses typically operate in a manner similar to motorcoaches. In practice, a number of definitions have been used. In the Safety Board's data report, a motorcoach is defined as any large bus with a GVWR greater than 26,000 pounds that is configured to carry more than 15 passengers and is being used as a charter/tour bus, in scheduled service, in commuter service, or as a shuttle bus. This definition would include the cross/country intercity bus type used in previous NHTSA and industry analyses and other types of buses that function as motorcoaches. Given that all large buses in the set of fatal accidents met the FARS V_CONFIG code equal to 21 (seats for more than 15 people, including driver), the following criteria were used to characterize motorcoaches:

a. All buses that met FARS BODY_TYP code 51 (Cross-Country/Intercity Bus).

[7] NHTSA's *Approach to Motorcoach Safety* (Washington, DC: DOT, 2007).

b. All buses with a FARS BODY_TYP code of 58 or 59 that met FARS BUS_USE code 4, 5, 6, or 7, and FARS GVWR code 3.

Step 4: Identify bus occupants. The analysis required evaluating bus occupant injuries and transport to hospital of bus occupants. Injured transported to a hospital were identified by using FARS INJ_SEV codes 1, 2, 3, 4, or 5 and FARS HOSPITAL code 1 (1, 7, or 8 for year 2000).

Bus occupants can be identified by using the FARS BODY_TYP variable in the Person File to determine the type of vehicle in which the person was an occupant. Bus occupants were identified by using the Person File FARS Body_TYP codes of 51, 52, 58, or 59.

Step 5: Identify whether rural or urban accident. Many of the analyses in this report compared rural and urban accidents. Selecting rural and urban accidents involving large buses was based on the FHWA's Roadway Function Classification system, a method typically used in the analysis of highway accident data to characterize rural or urban accidents. In this report, rural and urban accidents involving large buses were identified using FARS ROAD_FNC codes 1 through 9 for rural accidents and codes 11 through 19 for urban accidents.

Appendix C

Video Study[7]

The purpose of this study was to estimate the speed of the accident motorcoach just prior to roadway departure. To do so, Safety Board staff developed a computer program to analyze video recorded by the DriveCam II video recorder installed on the accident motorcoach.

DriveCam II Video Recorder Details

The MCI J4500 motorcoach in the Mexican Hat, Utah, accident was equipped with a DriveCam II video recorder that recorded video and accelerations. The DriveCam II system records color video frames at the rate of 4 per second (that is, at 0.25-second frame spacing) in 640×360 (H×V) format. The recording starts 10 seconds before a triggering event and lasts 10 seconds after it, for a total of 81 frames. The triggering event is an acceleration level that exceeds threshold 0.5 g for forward acceleration, 0.45 g for lateral acceleration, and 1.5 g for shock. The specific triggering event in this accident was shock acceleration above the threshold. The DriveCam II video recorder successfully captured the events before and during the accident. The camera was mounted on the right-front windshield of the motorcoach, close to the center post. The DriveCam II system includes two camera sensors, one forward-looking and one rearward-looking. Only the video from the forward-looking camera sensor was used in this study.

The DriveCam II system uses a wide-angle lens that exhibits barrel distortion near the edges of the images it captures. Safety Board staff calibrated the camera and mathematically corrected the distortion. The corrected images closely matched the images that an ideal pinhole camera would capture and that the analysis program is designed to handle.

Site Survey Data

The site of the Mexican Hat accident was accurately surveyed by Utah authorities. The survey included numerous fixed points on and off the roadway, including vehicle debris. From this survey, the video study used 183 surveyed points as landmarks for vehicle speed estimation, to include points representing the following:

- Solid white lines, solid yellow lines, and broken yellow lines on the roadway;
- Reflector locations, including 12 reflectors that were mounted on a guardrail;

[7] The material in this appendix is based on a video study prepared in support of the Mexican Hat, Utah, accident investigation; the study is available in the accident docket (HWY-08-MH-012).

- A post painted with reflective paint just past the last reflector and higher than it; and
- A large rectangular reflective “Valley of the Gods” road sign some distance past the last reflector.

Vehicle Speed Estimation

The Safety Board’s video analysis program can be used to determine the location of a moving vehicle by comparing the locations of landmarks in a camera image with their locations in a mathematically synthesized image generated by the program. If, at an assumed vehicle location, the camera image landmarks and synthesized image landmarks coincide, then the vehicle location is assumed to be where the vehicle was when the camera image was acquired.

Speed estimation is performed interactively. The user moves the vehicle that is displayed in the program’s graphical user interface (GUI) until the landmarks coincide. Vehicle speed can be estimated by dividing the distance between two vehicle locations by the time difference between the corresponding camera image frames. Figures C-1, C-2, and C-3 show the program GUI at times –7 seconds, –6 seconds, and –5 seconds, respectively. The vehicle is positioned at its estimated locations at those times. The lower plot in figures C-1 through C-3 shows the surveyed landmarks and the vehicle, with plot points corresponding to survey points representing the white solid lines on the pavement, the solid yellow lane-dividing line, the ends of broken yellow line segments, and the locations of reflectors. The upper plot is the camera image (shown as negative of the original), which shows the locations of the survey points as computed by the camera model that is built into the analysis program. Each reflector is marked at the elevation of the reflective surface and at ground level beneath it.

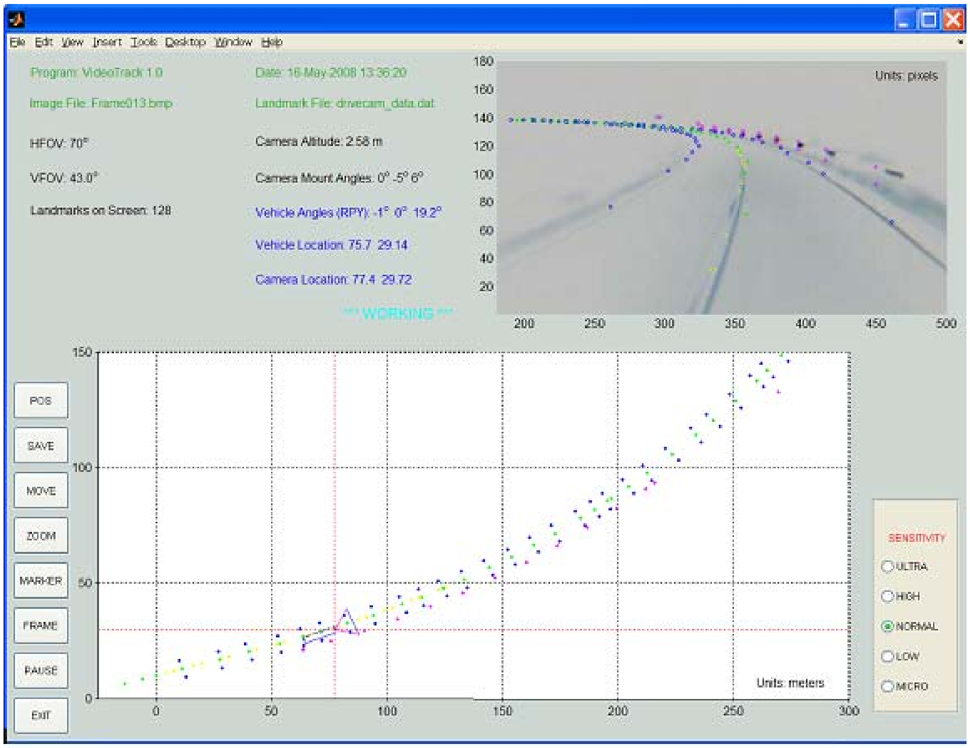

Figure C-1. Vehicle at time –7 seconds.

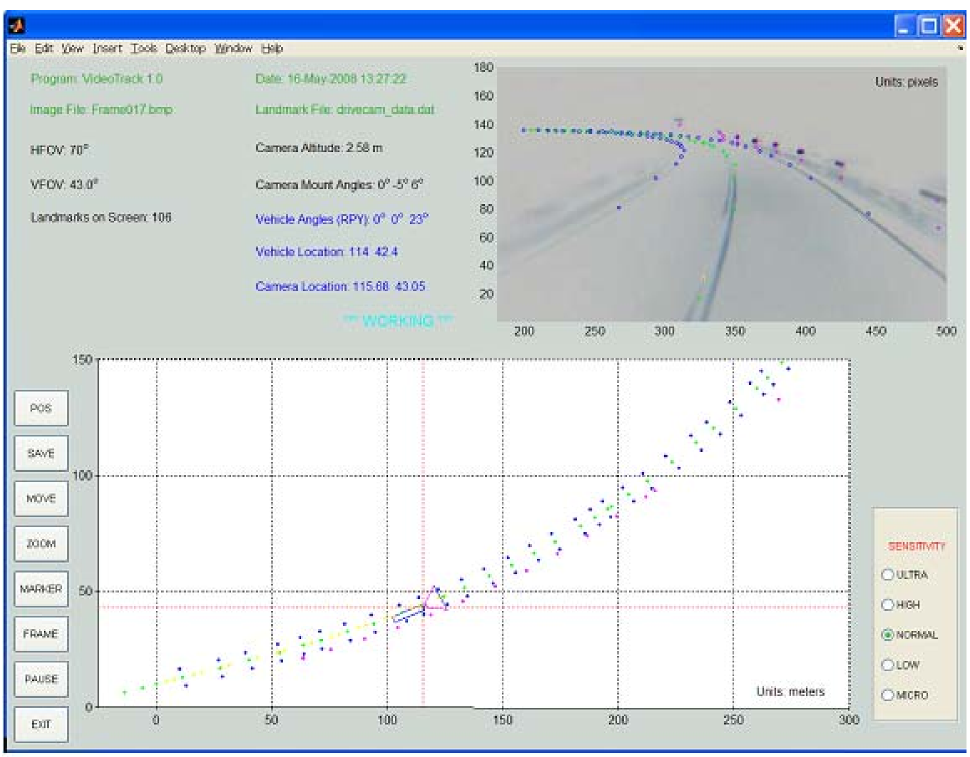

Figure C-2. Vehicle at time –6 seconds.

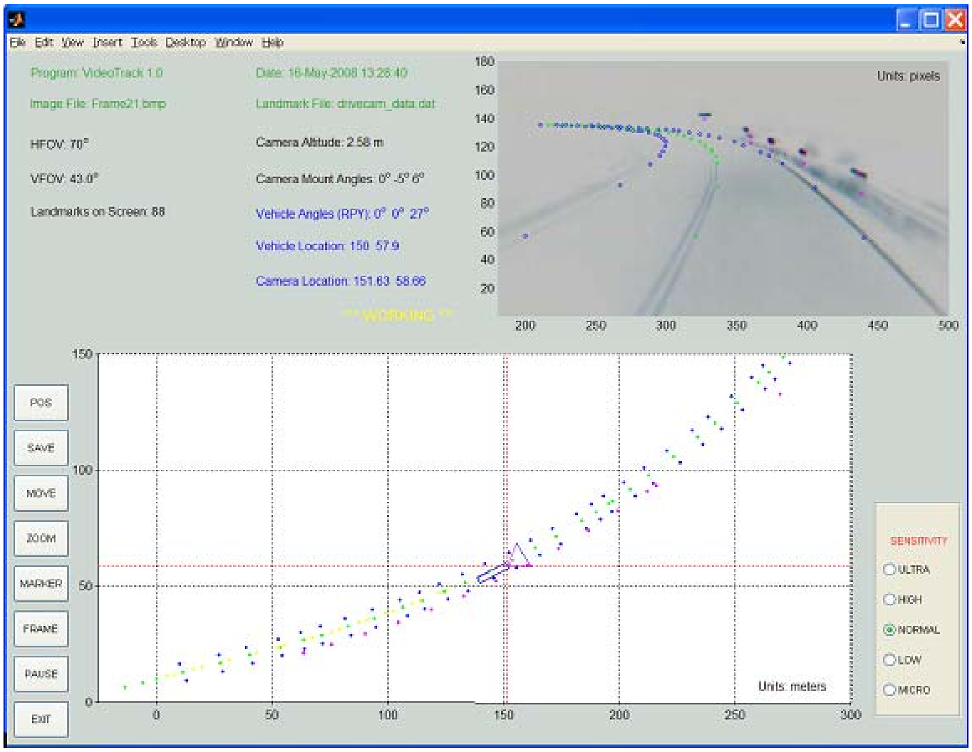

Figure C-3. Vehicle at time –5 seconds.

The motorcoach's location was estimated at 19 positions, corresponding to 19 camera frames spanning the time period from –8.75 to –4.25 seconds. The vehicle's speed was estimated using the formula $V_n = \Delta x / \Delta t$, where Δx is the total travel of the vehicle during n contiguous time intervals, and Δt is $0.25 \times n$. The middle line in the graph shown in figure C-4 represents this nominal speed estimate. The estimate becomes more accurate as more contiguous intervals are considered.

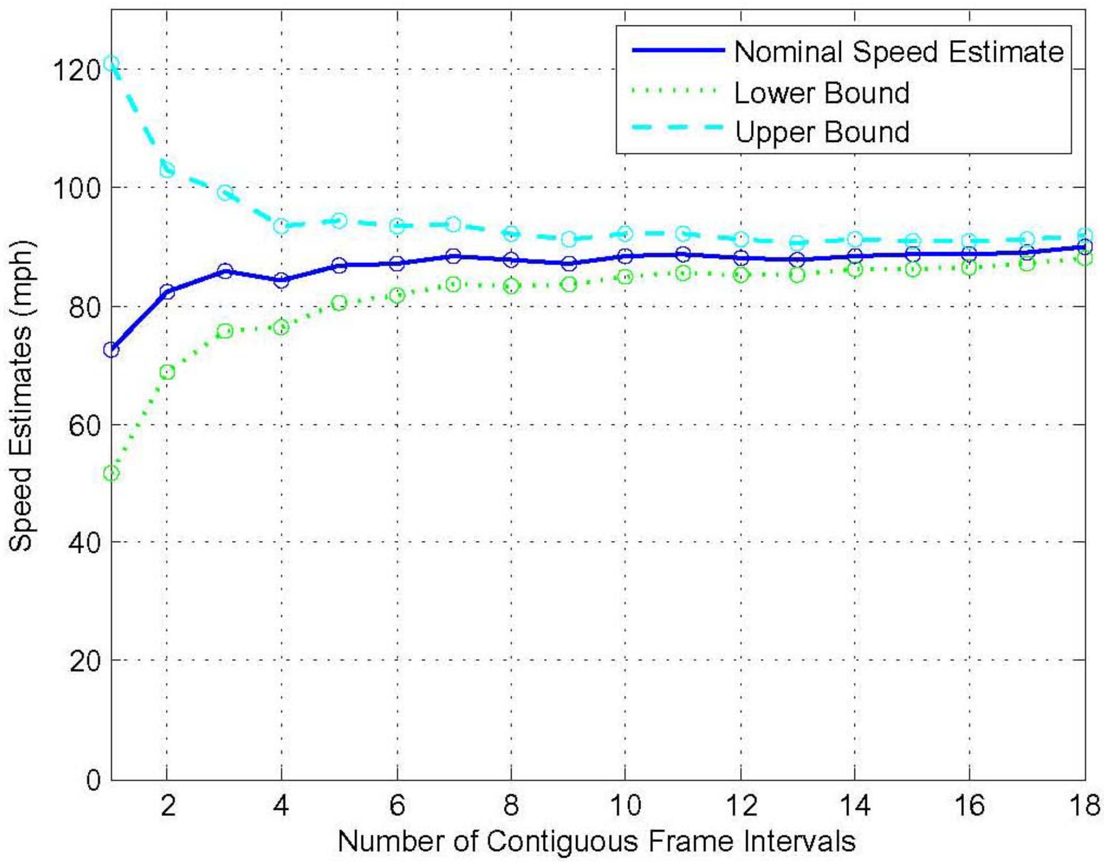

Figure C-4. Vehicle speed estimate versus number of frame intervals.

The nominal speed estimate is based on exact 0.25-second timing of the camera frame intervals. If camera timing is not exact, this nominal speed estimate could be too high (if the actual Δt was longer than 0.25×n) or too low (if Δt was shorter than 0.25×n). The possible speed estimation error due to such video frame timing was analyzed in detail and taken into account. The bottom line in the figure C-4 graph represents the lower bound of the speed estimate and the uppermost line represents the upper bound. The lower bound is higher than 85 mph if 10 or more camera frame intervals are considered. After 18 frame intervals, the lower bound of the motorcoach's speed is estimated to be 88 mph and the upper bound, 92 mph.

Summary of Results

Based on the Safety Board's analysis of video from the accident vehicle's DriveCam II video recorder, the motorcoach's speed was estimated to have been between 88 and 92 mph shortly before roadway departure.

Appendix D

Safety Board Motorcoach Accident Investigations

The National Transportation Safety Board's 1999 special investigation on bus crashworthiness[1] included statistics on 36 motorcoach accidents investigated by the Safety Board from 1968 through 1997. This appendix summarizes 33 motorcoach frontal crash and rollover accidents investigated by the Board (major accidents, field investigations, and incidents) since 1998. Table D-1 accounts for motorcoach passengers, not drivers, because drivers' use of seat belts decreases the likelihood of ejection.

Table D-1. Motorcoach accidents investigated by the Safety Board since 1998.

	Year	Accident	Fatalities	Injuries	Ejections	Crash type
1	1998	Burnt Cabins, PA (HWY-98-MH-033)	6	16	0	Frontal impact
2	1998	Old Bridge, NJ (HWY-99-MH-007)	8	14	7	Rollover
3	1999	Santa Fe, NM (HWY-99-FH-012)	2	35[A]	1	Rollover
4	1999	New Orleans, LA (HWY-99-MH-017)	22	21	10	Frontal impact[B]
5	1999	Braidwood, IL (HWY-99-FH-017)	1	23	2	Rollover
6	1999	Canon City, CO (HWY-00-FH-011)	2	57	53	Rollover
7	2000	Eureka, MO (HWY-00-IH-051)	0	25	0	Frontal impact
8	2001	Allamuchy, NJ (HWY-01-FH-011)	0	39	0	Rollover
9	2001	Bay St. Louis, MO (HWY-01-IH-024)	0	16	0	Frontal impact[B]
10	2001	Fairplay, CO (HWY-01-IH-028)	0	45	12	Rollover
11	2001	Pleasant View, TN (HWY-01-FH-03)	1	43	1	Rollover
12	2002	Manchester, TN (HWY-02-IH-002)	6	Unknown[C]	6	Rollover
13	2002	Loraine, TX (HWY-02-MH-021)	3	29	0	Frontal impact
14	2002	Victor, NY (HWY-02-MH-025)	5	41	6	Rollover
15	2002	Nephi, UT (HWY-03-IH-001)	6	20	13	Rollover
16	2003	Hewitt, TX (HWY-03-MH-022)	5	29	15	Rollover

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

	Year	Accident	Fatalities	Injuries	Ejections	Crash type
17	2003	Tallulah, LA (HWY-04-MH-002)	8	6	1	Frontal impact
18	2003	Apache Co., AZ (HWY-04-IH-007)	0	44	0	Rollover
19	2004	North Hudson, NY (HWY-04-FH-015)	0	47	0	Frontal impact
20	2003	Anahuac, TX (HWY-04-FH-026)	1	35	0	Frontal impact
21	2004	Phoenix, AZ (HWY-04-IH-029)	1	38	0	Frontal impact
22	2004	Jackson, TN (HWY-04-IH-035)	2	18	0	Frontal impact
23	2004	Turrell, AR (HWY-05-MH-006)	14	15	30	Rollover
24	2005	Geneseo, NY (HWY-05-FH-017)	3	20	0	Frontal impact
25	2005	Baltimore, MD (HWY-05-FH-031)	0	33	0	Rollover
26	2005	Osseo, WI (HWY-06-MH-003)	4	35	1	Frontal impact
27	2006	Westport, NY (HWY-06-MH-026)	4	48	22	Rollover
28	2006	Auburn, MA (HWY-06-IH-028)	0	34	0	Rollover
29	2007	Atlanta, GA (HWY-07-MH-015)	6	28	12	Frontal/rollover
30	2007	Clearfield, PA (HWY-07-IH-020)	2	25	2	Rollover
31	2007	Bowling Green, KY (HWY-07-IH-022)	1	64	10	Rollover
32	2008	Victoria, TX [D] (HWY-08-MH-001)	1	46	1	Rollover
33	2008	Mexican Hat, UT (HWY-08-MH-012)	9	44	50	Rollover
Total			123	1,033	255	

[A]Driver injuries unknown.

[B]Run-off-road, then frontal impact into terrain.

[C]Driver attacked by passenger; subsequent injuries unknown.

[D]Lap belts available; none reportedly were used.