Medium-Size Bus Roadway Departure, Return, and Rollover
Bryce Canyon City, Utah
September 20, 2019

Accident Report

NTSB/HAR-21/01
PB2021-100917

National Transportation Safety Board

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Notation 65959
Adopted May 10, 2021

Highway Accident Report

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National
Transportation
Safety Board

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

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Abstract: On September 20, 2019, a medium-size bus was traveling east on Utah State Route 12, a two-lane highway, near Bryce Canyon City, Utah. The bus was occupied by a 60-year-old driver and 30 passengers. Near mile marker 10.4, at a vehicle-recorded speed of about 64 mph, the bus's right wheels departed the right edge of the roadway. The driver steered left to return the bus to the roadway, a maneuver that redirected the bus into the westbound travel lane. The driver then steered sharply to the right, causing the bus to become unstable. It rolled 90 degrees, or a quarter turn, onto its left side. The bus slid on its left side until its roof struck the guardrail end treatment along the side of the westbound roadway and rolled over the guardrail, coming to rest on its wheels. No other vehicles were involved in the crash. Four passengers were fatally injured, 17 sustained serious injuries, and 9 sustained minor injuries. The bus driver was not injured. The safety issues discussed in the report of the crash concern the lack of requirements for vehicle technology to prevent medium-size bus road departures and rollovers, and the lack of occupant protection and crashworthiness standards for medium-size buses.

For more detailed background information on this report, visit the NTSB investigations website and search for NTSB accident ID HWY19MH012. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting—
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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Association for Testing and Materials
BCCVFD	Bryce Canyon City Volunteer Fire Department
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
CHP	California Highway Patrol
DOT	US Department of Transportation
ECM	engine control module
EMS	emergency medical services
ESC	electronic stability control
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standard
GVWR	gross vehicle weight rating
HOS	hours-of-service
LDP	lane departure prevention
LDW	lane departure warning
MAP-21	Moving Ahead for Progress in the 21st Century Act
MCS-150	motor carrier identification form (FMCSA)
MUTCD	*Manual on Uniform Traffic Control Devices for Streets and Highways*
NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
SR-12	(Utah) State Route 12
UDOT	Utah Department of Transportation

Executive Summary

Crash Summary

On Friday, September 20, 2019, about 11:30 a.m. mountain daylight time, a 2017 medium-size bus was traveling east on Utah State Route 12 (SR-12), a two-lane highway, near Bryce Canyon City in Garfield County, Utah. The posted speed limit was 65 mph, and the weather was clear and dry. The bus, which was operated by the motor carrier America Shengjia, was occupied by a 60-year-old driver and 30 passengers. The bus was carrying passengers on a tour that originated in Los Angeles, California, and was scheduled to end in Salt Lake City, Utah, on September 20. Bryce Canyon was the last stop before Salt Lake City.

Near mile marker 10.4 on SR-12, at a vehicle-recorded speed of about 64 mph, the bus's right wheels departed the right edge of the roadway. The driver steered left to return the bus to the roadway, a maneuver that redirected the bus into the westbound travel lane. The driver then steered sharply to the right, causing the bus to become unstable. It then rolled 90 degrees, or a quarter turn, onto its left side. The bus slid on its left side for about 85 feet, until its roof struck the guardrail end treatment along the side of the westbound roadway and rolled over the guardrail, coming to rest on its wheels after one complete roll. At final rest, the bus straddled the damaged guardrail, with its front end partially blocking the westbound travel lane of SR-12. No other vehicles were involved in the crash.

As a result of the crash, 4 passengers were fatally injured, 17 sustained serious injuries, and 9 sustained minor injuries. Thirteen passengers were either fully or partially ejected from the bus during the crash sequence. The bus driver was not injured. All rear seating positions were equipped with lap belts, and the driver and front passenger seats were equipped with lap/shoulder belts.[1]

Probable Cause

The National Transportation Safety Board determines that the probable cause of the Bryce Canyon City, Utah, crash was the bus driver's failure, for undetermined reasons, to maintain the bus within its travel lane and his subsequent steering overcorrections, which caused the bus to become unstable and roll over. Contributing to the severity of the crash was the roof's deformation, caused by the rollover, and its further collapse upon impact with the guardrail, which created ejection portals and compromised the survival space of the passenger seating compartment. Also contributing to the severity of the crash was the National Highway Traffic Safety Administration's failure to develop and promulgate standards for bus roof strength and window glazing to enhance the protection of bus passengers. Contributing to the ejections and the severity of the injuries was the lack of passenger lap/shoulder belts on the bus.

[1] For more information, see the factual information and analysis sections of this report. Additional information about the investigation of this crash (NTSB case number HWY19MH012) can be found by accessing the NTSB Docket Search Page. For more information on NTSB safety recommendations, see the Safety Recommendations Search Page.

Safety Issues

The safety issues identified in this investigation include the following:

- **Lack of requirements for vehicle technology to prevent medium-size bus road departures and rollovers**. The bus in this crash was a medium-size bus with a gross vehicle weight rating (GVWR) of 26,000 pounds. The bus was not equipped with lane departure warning or prevention systems, which help drivers maintain lane control. Nor was the bus equipped with electronic stability control, which helps drivers maintain control of a vehicle during extreme steering maneuvers. Although these technologies are available, they are not required to be installed on medium-size buses.

- **Lack of occupant protection and crashworthiness standards for medium-size buses**. Providing lap/shoulder belts, increasing roof strength, and improving window glazing would enhance the protection provided to occupants of medium-size buses. Research and federal regulation in these areas have typically excluded certain medium-size buses with GVWRs between 10,000 and 26,000 pounds. Occupants of such buses should have the same level of protection as is afforded to occupants of large motorcoaches.

Findings

1. None of the following were factors in this crash: (1) mechanical operation of the bus; (2) design, markings, signage, or friction characteristics of the highway; (3) motor carrier operations or state or federal oversight of the motor carrier; (4) driver experience, licensing, alcohol or drug use, fatigue, distraction, or medical issues; and (5) weather or illumination.

2. The emergency response and the transportation of the injured passengers were timely and adequate.

3. The bus driver failed to keep the bus within the travel lane for undetermined reasons, and the bus's right-side tires left the roadway.

4. The driver responded to the bus's departure from the roadway first by overcorrecting to the left to reenter the roadway, and then by overcorrecting to the right, after the bus had begun to enter the opposing travel lane; these overcorrections caused the bus to become unstable and to roll over.

5. Had the bus been equipped with an electronic stability control system, the technology would have assisted the driver in maintaining control of the bus and reduced the likelihood of vehicle rollover.

6. The safety of buses with gross vehicle weight ratings between 10,000 and 26,000 pounds would be enhanced by equipping them with electronic stability control systems.

7. The lane markings on State Route 12 were visible and in good condition; therefore, a lane departure warning or prevention system should have been able to detect and recognize the lane markings and provide appropriate alerts or action in response to the bus's departure from the lane.

8. A lane departure warning system on the bus would have alerted the driver that the bus was departing its travel lane, while a lane departure prevention system would have actively assisted the driver to keep the vehicle within the travel lane if he did not react to a warning; either technology might have prevented the series of events that led to the crash.

9. Because some bus passengers did not wear their lap belts and others wore them improperly, the likelihood of these passengers experiencing ejection and/or injury during the rollover crash was increased.

10. In this crash, properly worn lap/shoulder belts, as opposed to lap-only belts, would have provided a higher level of protection to the bus passengers.

11. Passengers of all types of medium-size buses should be afforded the same level of occupant protection as passengers on buses with gross vehicle weight ratings over 26,000 pounds, including the availability of lap/shoulder belts at all seating positions.

12. As demonstrated by this medium-size bus crash, structural improvements to enhance roof strength and advanced window glazing are needed to help maintain survival space and reduce the risk of ejection for bus occupants.

13. Because the National Highway Traffic Safety Administration has failed to establish roof strength and window glazing standards for buses with gross vehicle weight ratings above 10,000 pounds, the occupants of these buses have been inadequately protected during crashes, particularly rollover crashes.

Recommendations

New Recommendations

To the National Highway Traffic Safety Administration:

Require all newly manufactured commercial motor vehicles with gross vehicle weight ratings above 10,000 pounds to be equipped with lane departure prevention systems. (H-21-1) *[This new recommendation supersedes Safety Recommendation H-10-1.]*

Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions. (H-21-2) *[This new recommendation supersedes Safety Recommendations H-99-50 and -51 and H-10-3, and it is initiated with the status "Open—Unacceptable Response."]*

Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a window glazing standard that prevents occupant ejection. (H-21-3) *[This new recommendation supersedes Safety Recommendations H-99-49 and H-10-3, and it is initiated with the status "Open—Unacceptable Response."]*

Previously Issued Recommendations Reiterated in This Report

To the National Highway Traffic Safety Administration:

Develop stability control system performance standards for all commercial motor vehicles and buses with a gross vehicle weight rating greater than 10,000 pounds, regardless of whether the vehicles are equipped with a hydraulic or a pneumatic brake system. (H-11-7)

Once the performance standards from Safety Recommendation H-11-7 have been developed, require the installation of stability control systems on all newly manufactured commercial vehicles with a gross vehicle weight rating greater than 10,000 pounds. (H-11-8)

Safety Recommendations H-11-7 and -8 are reiterated in section 2.3.1 of the report.

Amend Federal Motor Vehicle Safety Standard 208 to require lap/shoulder belts for each passenger seating position on all new buses with a gross vehicle weight rating of more than 10,000 pounds but not greater than 26,000 pounds. (H-18-59)

Safety Recommendation H-18-59 is reiterated in section 2.4.1 of the report.

To the bus manufacturers ARBOC Specialty Vehicles, LLC; Coach & Equipment Manufacturing Corporation; Rev Group, Inc.; Diamond Coach Corporation; Forest River, Inc.; Girardin Blue Bird; SVO Group, Inc.; and Thomas Built Buses:

Install lap/shoulder belts in all seating positions as standard, rather than optional, equipment in all newly manufactured medium-size buses. (H-18-62)

Safety Recommendation H-18-62 is reiterated in section 2.4.1 of the report.

To the bus seat manufacturers Freedman Seating Company and HSM Transportation Solutions:

Supply seating systems equipped with lap/shoulder belts as standard, rather than optional, equipment for medium-size buses. (H-18-63)

Safety Recommendation H-18-63 is reiterated in section 2.4.1 of the report.

Previously Issued Recommendations Classified in This Report

To the National Highway Traffic Safety Administration:

> Expand your research on current advanced glazing to include its applicability to motorcoach occupant ejection prevention, and revise window glazing requirements for newly manufactured motorcoaches based on the results of this research. (H-99-49)

The classification of Safety Recommendation H-99-49 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-3 in section 2.4.2 of this report.

> 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)

The classification of Safety Recommendation H-99-50 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-2 in section 2.4.2 of this report.

> Once performance standards have been developed for motorcoach roof strength, require newly manufactured motorcoaches to meet those standards. (H-99-51)

The classification of Safety Recommendation H-99-51 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-2 in section 2.4.2 of this report.

> Require new commercial motor vehicles with a gross vehicle weight rating above 10,000 pounds to be equipped with lane departure warning systems. (H-10-1)

The classification of Safety Recommendation H-10-1 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-1 in section 2.3.2 of this report.

> In your rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a gross vehicle weight rating above 10,000 pounds, other than school buses. (H-10-3)

The classification of Safety Recommendation H-10-3 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendations H-21-2 and -3 in section 2.4.2 of this report.

1 Factual Information

1.1 Crash Narrative

On Friday, September 20, 2019, about 11:30 a.m. mountain daylight time, a 2017 medium-size bus, consisting of a Freightliner chassis and an Embassy bus body, was traveling east on Utah State Route 12 (SR-12) near Bryce Canyon City in Garfield County, Utah (see figure 1).[1] The bus was a tour bus operated by the motor carrier America Shengjia, and it was occupied by a 60-year-old driver and 30 passengers.

The tour group had arrived in Los Angeles, California, from China on September 14, 2019, for the first leg of a sightseeing tour of the United States. This segment of the trip was scheduled to end in Salt Lake City, Utah, on September 20.[2] On the day of the crash, the group departed Hurricane, Utah, for a scheduled stop at Bryce Canyon National Park before proceeding to Salt Lake City. The group took a rest break in Orderville, Utah, from 10:00 a.m. to 10:30 a.m. and then continued toward Bryce Canyon. The crash occurred about 10.4 miles from the park entrance.

Figure 1. Map of crash location.

[1] Unless otherwise indicated, all times in the report are mountain daylight time.

[2] From Salt Lake City, another motor carrier was to provide transportation for the tour group as it continued to Yellowstone National Park and the East Coast of the United States, before returning to China.

In the area where the bus was traveling, SR-12 is a two-lane undivided roadway with a slight curve to the right for eastbound traffic (see figure 2 for an orthomosaic aerial image of the crash scene).[3] The eastbound lane widens to create a dedicated left-turn lane for traffic entering a rest area to the north of the roadway. The westbound lane widens to create a dedicated right-turn lane for traffic entering the rest area. The posted speed limit in the area is 65 mph.

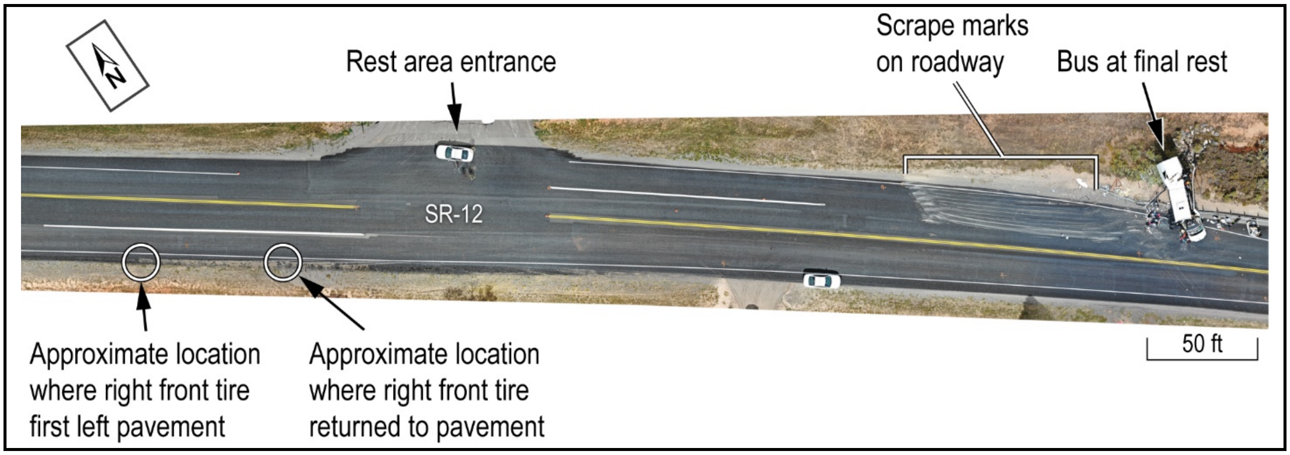

Figure 2. Orthomosaic aerial image of crash scene on SR-12. (Source: Utah Highway Patrol, with labeling added by the NTSB)

Near mile marker 10.4, at a vehicle-recorded speed of 64 mph, the right-side wheels of the bus departed the right edge of the roadway (see figure 3).[4] The bus driver steered the bus to the left and returned it to the roadway, redirecting the bus into the westbound travel lane. A delineator post that was struck (sideswiped) by the bus as it returned to the roadway is indicated in figure 3.

[3] An *orthomosaic* image is a combination of numerous individual images processed by computer software such that the photographs are geometrically corrected for scale and to remove distortion.

[4] The bus departed the roadway about 1,306 feet into an approximately 2,143-foot-long right-hand horizontal curve and about 220 feet into an 800-foot-long vertical curve. The vertical curve was a type II crest vertical curve connecting a flatter downhill slope to a steeper downhill slope.

Figure 3. Location where bus left roadway and then returned, with struck delineator post indicated by arrow and label.

Figure 4 shows tire marks from the bus as it returned to the roadway. The driver then steered sharply to the right, causing the bus to roll 90 degrees (or a quarter turn) onto its left side in the westbound lane. (Figure 5 shows the tire marks from the bus as the driver overcorrected to the right.) The bus slid on its left side for about 85 feet (see figure 6 for gouge marks) until its roof struck the guardrail end treatment next to the westbound travel lane (see figure 7). The bus continued to roll over the guardrail another three-quarters of a turn, landing about 43 feet farther east and coming to rest upright on its tires on top of the guardrail, having completed one full roll during the crash.

Figure 4. Tire marks curving across eastbound travel lane after bus departed roadway and was steered back. (Source: Utah Highway Patrol)

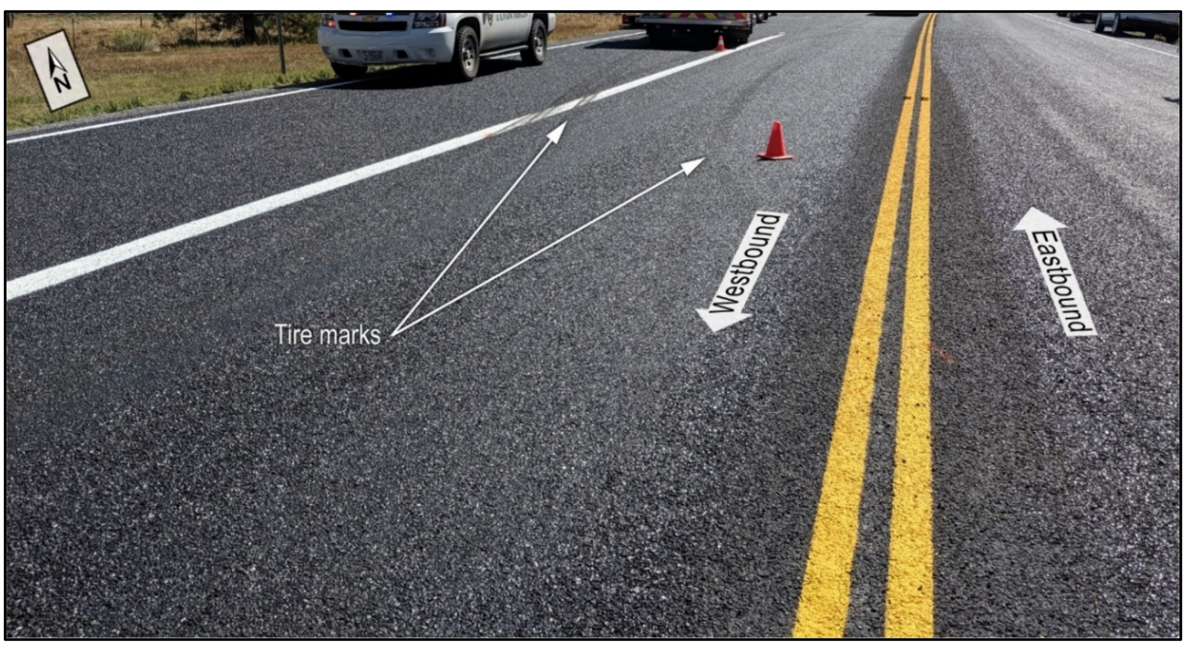

Figure 5. Tire marks curving from westbound toward eastbound lane. (Source: Utah Highway Patrol)

Figure 6. Gouge marks on westbound lane pavement left by bus sliding toward guardrail.

Figure 7. Damaged guardrail on westbound side of SR-12. (View is looking east.)

At final rest, the bus straddled the damaged guardrail, with its front end partially blocking the westbound traffic lane of SR-12 (see figure 8). No other vehicles were involved in the crash.

Figure 8. Bus at final rest on top of guardrail. (Source: Utah Highway Patrol)

1.2 Injuries

All 30 passengers were injured in this crash (see table 1). Four passengers were fatally injured, 17 sustained serious injuries, and 9 sustained minor injuries. The bus driver was not injured.

Table 1. Injury severity of bus occupants.

Injury Severity[a]	Fatal	Serious	Minor	None	Total
Bus driver	0	0	0	1	1
Bus passengers	4	17	9	0	30
TOTAL	4	17	9	1	31

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

Figure 9 summarizes information on bus occupant seating position, ejection, and injury severity. Appendix C provides detailed information on occupant seat belt use. (According to Utah's Motor Vehicle Safety Belt Usage Act, anyone age 16 or older who is a passenger in a motor vehicle operated on a highway is required to wear a properly adjusted and fastened safety belt.)

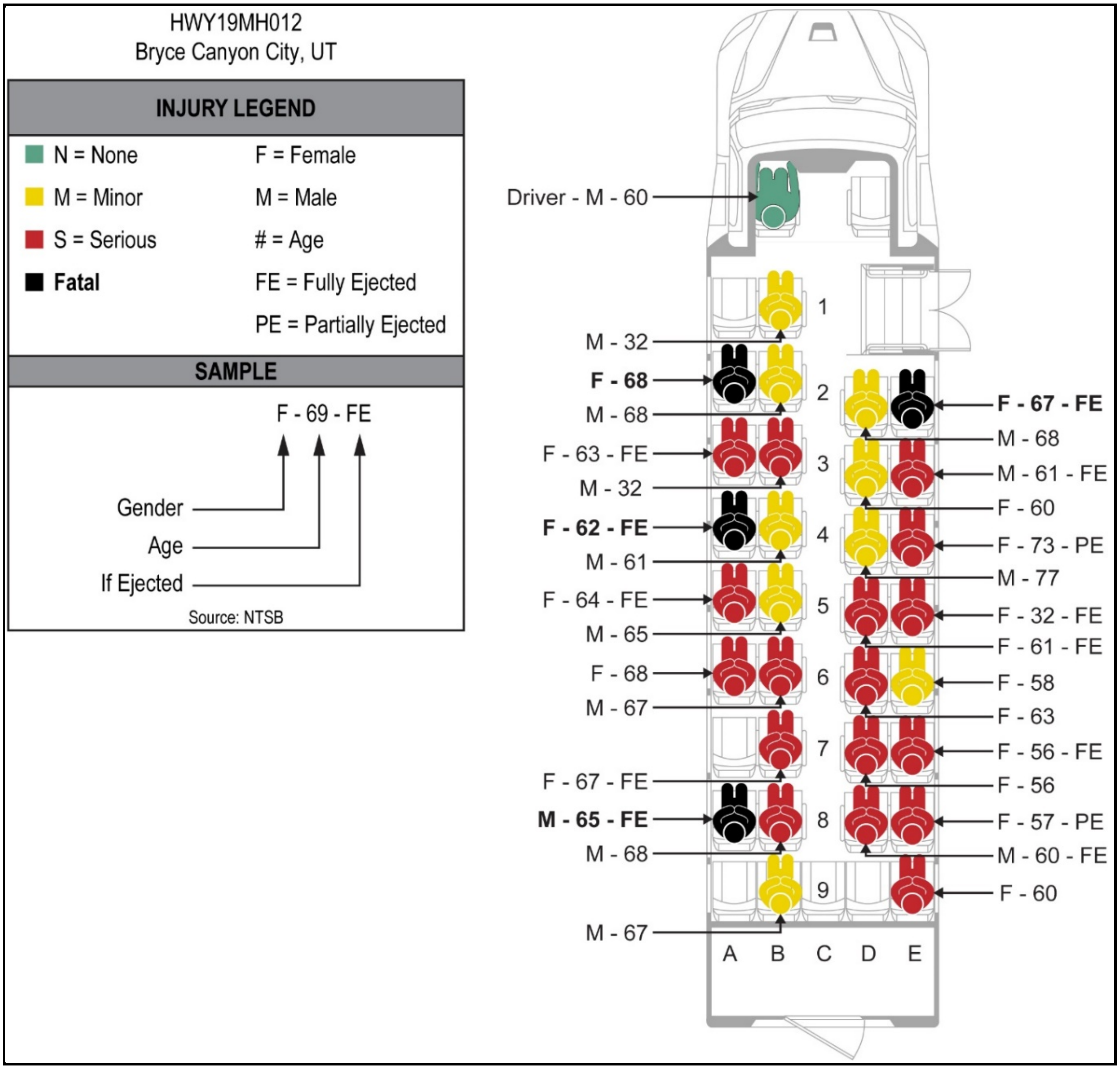

Figure 9. Bus seating chart, showing occupants' seating positions and injury severity.

The driver and front passenger seats were equipped with lap/shoulder belts, and the seats in the passenger compartment were equipped with lap belts. Following the crash, investigators determined occupant seat belt use through interviews or by evidence of physical injuries, such as abdominal bruising or abrasions.[5] Eleven passengers were fully ejected from the bus and came to rest on the westbound roadway. Three sustained fatal injuries (these passengers' lap belt use is unknown), and eight sustained serious injuries (four of these passengers were belted, one was unbelted, and the seat belt use by three could not be determined). Two additional passengers were

[5] (a) All the bus occupants were non-English-speakers; an interpreter assisted with the interviews. (b) Lap belt use is indicated by patterned bruising on the user's abdominal wall, corresponding to the position of the lap belt (sometimes referred to as seat belt syndrome).

partially ejected during the rollover (their legs remained within the bus). Both were lap-belted and sustained serious injuries. The passenger seated on the driver side of the bus in the window seat of the second passenger row remained inside the bus but was displaced from her seat into the boarding stairwell; she sustained fatal injuries. According to an interview with her spouse, who had been seated next to her on the bus, she had been loosely lap-belted. Of the remaining passengers who were not ejected from the bus, seven sustained serious injuries (six were lap-belted and one was unbelted), and nine sustained minor injuries (seven were lap-belted, and the belt use by two could not be determined). The driver was wearing his lap/shoulder belt at the time of the crash.

1.3 Emergency Response

The Garfield County Sheriff's Office was notified of the crash through the 911 system at 11:32 a.m. and relayed the information to dispatchers at the Utah Department of Public Safety Richfield Communications Center at 11:33 a.m.[6] The Bryce Canyon City Volunteer Fire Department (BCCVFD) and several Garfield County ambulance services were dispatched between 11:35 a.m. and 11:37 a.m. A BCCVFD ambulance was the first emergency medical services (EMS) unit to arrive on scene, at 11:41 a.m. The first Utah Highway Patrol unit arrived at 11:48 a.m. In total, 12 local and state police, fire, and EMS agencies responded to the crash.[7] One volunteer firefighter/emergency medical technician spoke Mandarin and assisted with triage.

Within 2 hours of the crash, 26 passengers were transported from the crash scene. Passengers were transported by ambulance and treated at Garfield Memorial Hospital (17 miles away), Kane County Hospital (75 miles away), Servier Valley Hospital (100 miles away), Dixie Regional Medical Center (140 miles away), and Utah Valley Medical Center (225 miles away). The more seriously injured passengers were flown for treatment to the Dixie Regional and Utah Valley Medical Centers, the higher-level trauma hospitals among these facilities.

1.4 Vehicle Information

1.4.1 General

Bus Build. The bus consisted of a 2017 Freightliner M2 chassis with an Embassy medium-size bus body. It was manufactured in three stages. The first build stage of the cab and chassis, known as an incomplete vehicle or commercial cutaway, was completed by Freightliner in December 2016. The second build stage consisted of configuring the truck's chassis and was completed in February 2017 by MOR/Ryde International. SVO Group completed the third and final build stage by configuring the vehicle with a medium-size Embassy bus body in

[6] The Richfield Communications Center is the public safety answering point for Millard, Piute, Sevier, and Wayne Counties. The center provides communication services to Garfield, Juab, Kane, and Sanpete Counties. The center dispatches state and federal law enforcement, police, fire, and other emergency services.

[7] These included the Utah Highway Patrol, Garfield County Sheriff's Department, BCCVFD, Tropic Volunteer Fire Department, Henryville Volunteer Fire Department, Panguitch Fire Department, Piute County Ambulance (Marysvale), Kane County Ambulance (Kanab), Classic Medical Helicopter and Fixed Wing, Intermountain Healthcare Helicopter Medivac, Bryce Canyon State Park (forest rangers and medical staffers), and Utah Department of Transportation.

February 2017. The completed vehicle's gross vehicle weight rating (GVWR) was 26,000 pounds.[8]

At the time of manufacture, the bus was 456 inches long and 99 inches wide. A luggage storage compartment, about 40 inches deep, was located across the rear of the bus, behind the last row of seats; it was accessible solely from the rear of the bus. An additional 60-inch-wide by 24-inch-high luggage storage compartment was located under the floor of the bus and was accessible through a flip-up door to the compartment on the lower right (passenger) side of the bus. There were overhead luggage racks along each side of the bus's interior, above the rows of passenger seating.

Bus Type. The bus was both a medium-size bus and an over-the-road bus. A medium-size bus is typically referred to as such because the body is built on a medium-duty truck chassis. The weight range for a medium-size bus is 10,001 to 26,000 pounds GVWR.[9] Because this bus had an elevated passenger deck located over a baggage compartment, it also is categorized as an "over-the-road bus" (Transportation Equity Act for the 21st Century, Public Law 105–178, section 3038[a][3]).

Equipment. The driver and front passenger seats were bucket-style seating equipped with lap/shoulder belts. The bus was not equipped with air bags. In the passenger compartment of the bus body were eight rows of two-person seats on the driver side and seven rows of two-person seats on the passenger side. The last row of the compartment consisted of five seats in a single row across the interior width of the bus. Each of the 35 rear passenger seats was equipped with a lap belt attached to the back of the seat frame.[10]

Postcrash, National Transportation Safety Board (NTSB) investigators found the steering, braking, and suspension systems to be operational and undamaged. The bus was equipped with air brakes, and none of the brakes were found to be out of adjustment. No defects were found within the engine components. The electrical systems were operational; however, the required lamps and reflective devices were damaged during the crash. All the tires were inspected postcrash, and no defects (other than minor crash-related damage) were noted. All tire tread depths exceeded the minimum tread depths specified for commercial vehicles (per 49 *Code of Federal Regulations* [*CFR*] 393.75). Maintenance and inspection records obtained from America Shengjia detailed regular service intervals. All warranty claims on this vehicle pertained to cosmetic scratches, and no claims for mechanical issues were documented. Freightliner had not issued any recalls on the vehicle.

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[8] *GVWR* is the maximum operating weight of a vehicle as specified by the manufacturer. Title 49 *Code of Federal Regulations* 567.4 states that the GVWR "shall not be less than the sum of the unloaded vehicle weight, rated cargo load, and 150 pounds times the vehicle's designated seating capacity."

[9] The specific attributes of what constitutes a "medium-size bus" vary somewhat among regulatory authorities and industry groups. For a discussion of some of the specific definitions, see the NTSB's report of its investigation of a bus loss of control and rollover crash near Dolan Springs, Arizona, on January 30, 2009 (NTSB 2010, pp. 22–28).

[10] (a) The seats were manufactured by Freedman Seating Company, and the lap belts were manufactured by Shield Restraint Systems. (b) One bolt attached the latch plate portion of the seat belt to the frame and a second bolt attached the buckle portion to the frame. These were spaced 11.5 inches apart. (c) Users had to manually adjust the lap belts, and they had no automatic retractors.

Although Freightliner offered electronic stability control (ESC) and lane departure warning (LDW) systems as optional equipment when the bus was manufactured, SVO Group did not purchase the systems when it ordered the chassis. Freightliner did not offer lane departure prevention (LDP) systems at the time of manufacture.[11]

1.4.2 Damage

The front of the Freightliner bus had minor damage (see figures 10 and 11). The fiberglass roof of the cab was torn and displaced rearward. The front windshield was shattered and displaced from the frame. The driver's door would not close due to damage to the frame; the passenger cab door was operational.

The rear bumper was displaced upward on the right side. The fiberglass body was damaged and torn on both the top right and left rear corners.

Figure 10. Damage on left side of bus.

[11] (a) AAA has identified 19 names used to describe LDW and LDP systems. In this report, the NTSB uses the term LDW to describe a system that uses technology to alert a driver when the vehicle is on a trajectory to travel out of its lane and the driver must respond with braking or steering input to keep the vehicle in the lane, and the term LDP to describe a system that uses technology to actively keep a vehicle from drifting out of its lane by automatically applying braking or steering input. (See AAA January 2019 Advanced Driver Assistance Technology Names Research Report, accessed March 16, 2021.) (b) Freightliner now offers active lane assist systems as part of its Detroit Assurance 5.0 safety system. See Detroit Assurance brochure, accessed March 16, 2021.

Figure 11. Damage on right side of bus.

As shown in figures 10 and 11, the fiberglass panels on the left and right sides of the bus were damaged and torn.[12] All windows on both sides, including the emergency windows, were displaced and broken. A 6-inch by 8-inch wood guardrail post was embedded in the right side of the bus, at a point about 20 feet back from the front bumper and just beyond the underfloor luggage compartment. The frame of the passenger boarding door (located behind the passenger cab door on the passenger side of the bus) was damaged, and the glass on the left side of the bifold boarding door was missing.

The bus sustained extensive roof damage with significant intrusion into the occupant space. The roof was displaced and shifted to the right about 31 inches. The left side of the roof was crushed downward, exposing the tops of the passenger seats next to the left sidewall. The overhead luggage racks remained attached to the collapsed roof on both sides of the bus. The emergency roof hatch was found closed and damaged; it could not be fully opened. Postcrash, the fiberglass roof and structural metal bows were separated from the metal sidewall frame mounts on both the left and right sides. Examination of the joint welds indicated that they were adequate.

[12] For uniform description, "left" will refer to the driver's side, and "right" will refer to the passenger side of the vehicle.

1.4.3 Seat Belts

The bus driver's lap/shoulder belt was found unbuckled, retracted, and hanging from the upper attachment point to the left of the driver's seat. There was visible evidence of loading (heat abrasion and cupping) on the shoulder belt webbing.

The passenger seat frames remained intact and attached to the base frame, floor, and sidewall. Postcrash, five passenger lap belts were found buckled; three of the buckled belts were on seats from which passengers were ejected or displaced. (See appendix C for additional detail on seat belt use.)

NTSB investigators removed the lap belts from seats 2A (passenger displaced from seat, seat belt loosely worn [confirmed by spouse]), 4D (seat belt used, no ejection), 5A (seat belt used, passenger fully ejected), 7A (seat empty during crash), and 7B (seat belt used, passenger fully ejected) for examination in the NTSB Materials Laboratory.[13] The examination did not reveal any evidence that the lap belt buckles were prone to improper release or malfunction. None of the buckles released unless the examiner depressed the release button. According to documentation from Shield Restraint Systems, the seat belts met applicable federal requirements and did not show any evidence of nonconforming parts.

1.4.4 Event Data

The vehicle's engine was electronically controlled by an engine control module (ECM) that monitored performance, fuel efficiency, and emissions based on various engine and sensor inputs. The ECM also recorded parameters, such as vehicle speed and engine speed, triggered by a hard-brake event.[14] The data indicated that the bus's speed varied within the range of 64–74 mph before the hard-brake event associated with the crash. Table 2 shows the data from the ECM for 5 seconds before and after the hard-brake trigger event.

[13] (a) This report references the passenger seating positions by row, with row 1 being the first behind the bus driver, and by letter, with seats A and B being the window and aisle seats, respectively, on the driver's side of the bus. Seats D and E are the aisle and window seats, respectively, on the passenger side of the bus. Row 1 had only two seating positions, and row 9 had five seating positions, while all the other rows had four seating positions. (b) Investigators removed the lap belts from seats 4D and 5A immediately after the crash and the lap belts from seats 2A, 7A, and 7B on November 19, 2019.

[14] A *hard-brake event* recording is triggered when the vehicle deceleration exceeds a preset level (9.01 mph/second on this vehicle). Each hard-brake event record contains 15 seconds of post-trigger data and 1 minute of pretrigger data, recorded at 1-second intervals.

Table 2. Hard-brake event data recorded by engine control module.

Time (seconds)	Speed (mph)	Engine Speed (revolutions per minute)	Engine Load %	Throttle %	Brake Status
-5	64	2023	0.0	21.2	Off
-4	64	2010	0.0	0.0	Off
-3	61	1901	0.0	0.0	On
-2	56	1777	0.0	0.0	On
-1	53	1462	0.0	0.0	Off
0	46	881	0.0	0.0	On
1	37	886	0.0	0.0	Off
2	31	571	0.0	0.0	Off
3	26	143	0.0	0.0	Off
4	16	0	0.0	0.0	Off
5	15	0	0.0	0.0	Off

1.5 Highway Information

1.5.1 General

The crash occurred on eastbound SR-12 at milepost 10.4 near Bryce Canyon City, Garfield County, Utah. In the area of the crash, SR-12 is a two-lane asphalt-paved roadway that widens to accommodate a dedicated left-turn lane for eastbound traffic and a dedicated right-turn lane for westbound traffic to enter a rest area on the northeast side of the highway (see figure 12). In the area of the crash, SR-12 is functionally classified as a rural principal arterial roadway; it is also a federally designated bicycle route.[15] The posted speed limit for the area is 65 mph.

The eastbound travel lane was 11 feet, 4 inches wide. To the right of the travel lane was an approximately 2-foot-wide asphalt paved shoulder, and a gravel shoulder that was 3 feet wide. There was a drop of about 3 inches between the paved and gravel shoulders.[16] The westbound

[15] The American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* describes a rural principal arterial system as a network of routes with the following service characteristics: (1) corridor movement with trip length and density suitable for substantial statewide or interstate travel; (2) movements between all, or virtually all, urban areas with populations over 50,000 and a large majority of those with populations over 25,000; and (3) integrated movement without stub connections, except where unusual geographic or traffic flow conditions dictate otherwise. (AASHTO 2018, section 1.4.3.3.1.)

[16] (a) All measurements are approximate and were taken in the area where the bus first left the roadway. (b) The total width of the paved shoulder, measured from the center of the fog line to the pavement edge, was approximately 2 feet. The Utah Department of Transportation provided additional measurements, excluding the pavement that had been tapered to match the side slope of the gravel shoulder, which indicated that the paved shoulder had an effective width that varied between 7 and 12 inches. (c) The pavement-edge drop-off measurement at this location was taken after both the front and rear bus tires had traveled over this portion of the shoulder, which compacted and disturbed the gravel. Eight additional pavement drop-off measurements were taken along the east- and westbound shoulders of SR-12 in the vicinity of the crash; all those measurements were 2 inches or less. The roadway edge immediately east of this location, along the travel path of the bus, was further damaged and was broken away and displaced by the bus during its attempt to return to the roadway. (d) According to AASHTO's *Roadside Design Guide*, mitigating measures should be considered for pavement edge drop-offs greater than 3 inches that are immediately adjacent to traffic (AASHTO 2011, section 9.5.2).

travel lane was 12 feet, 9 inches wide; the asphalt-paved shoulder was 5 feet wide; and the gravel shoulder was 3 feet wide. The yellow solid double lines separating the east- and westbound travel lanes were 4 inches wide. The white solid line separating the eastbound travel lane from the left turn lane was 8 inches wide, and the white solid lines separating the travel lanes from the paved shoulders were 4 inches wide. The regulatory and warning signage conformed to the Federal Highway Administration (FHWA) *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) guidance (FHWA 2009).

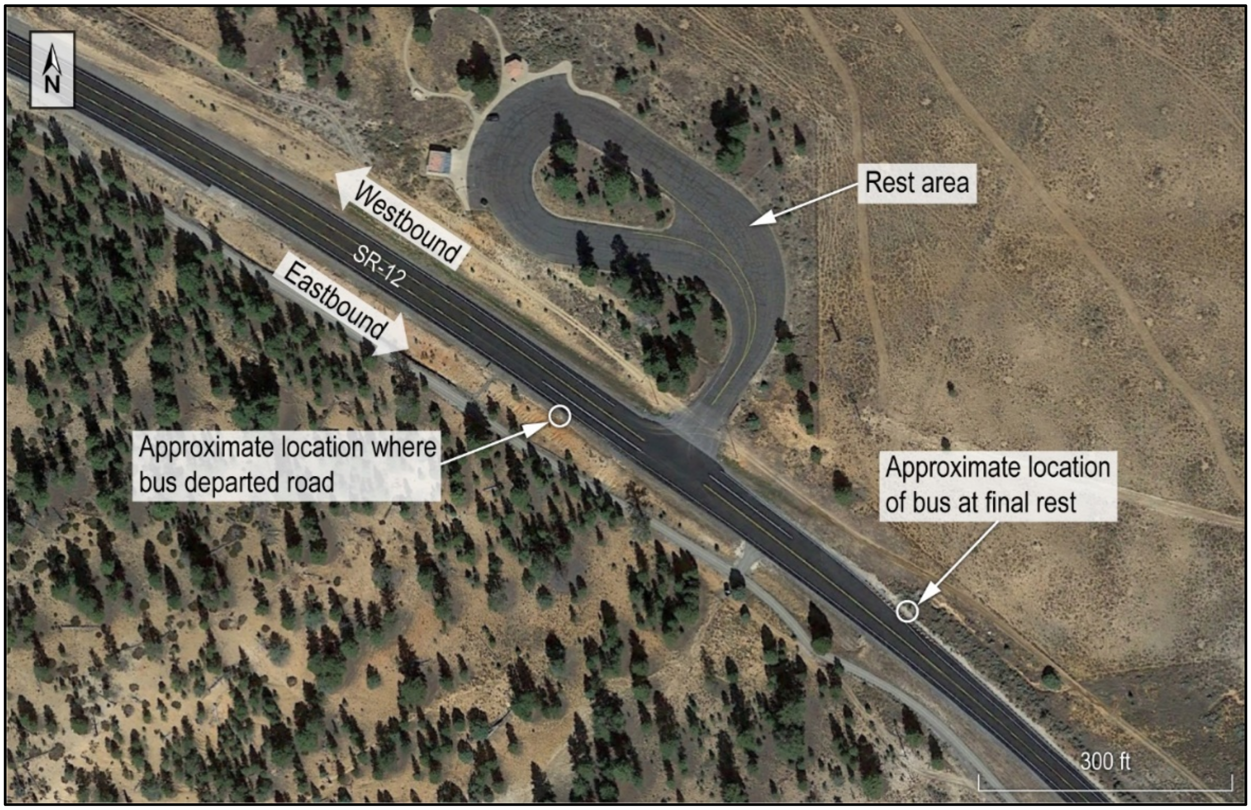

Figure 12. Crash location. (Source: Google Earth [labels added by the NTSB])

A 1,312-foot-long section of blocked-out strong post W-beam guardrail was installed along the westbound travel lane. Both ends of the guardrail were equipped with energy-absorbing terminals.

There were no rumble strips along the eastbound shoulder of SR-12 in the vicinity of the crash, due to the narrow shoulders along the section of roadway that had been widened to accommodate the rest area turn lanes, or on the westbound shoulder, due to the entrance to the rest area. Rumble strips, however, were present along the shoulders of SR-12 before and after the crash location, where the paved shoulders were wide enough to accommodate them. Continuous centerline rumble strips were scored into the roadway at the crash location. The rumble strips in the vicinity of the crash were found to provide auditory and vibration feedback. FHWA guidance suggests that there be 4 feet beyond the rumble strip to the edge of the paved shoulder to help the roadway accommodate bicyclists.[17] According to the Utah Department of Transportation (UDOT) standard, paved shoulders on bicycle routes should be at least 3 feet wide to allow the installation of rumble strips.[18]

The crash occurred within a right horizontal curve with a radius of about 5,730 feet. The roadway had a 0.7-percent downhill grade at the location where the bus first left the highway. The width of the clear zone in the area where the bus first departed the roadway, measured from the edge of the traveled way to the tree line south of the roadway, was about 44 feet.[19] Clear zone side-slope ratios in the area where the bus went off the roadway ranged from 3.9:1 to 5.8:1.[20]

1.5.2 Highway Maintenance

In 2011, UDOT resurfaced SR-12 between mileposts 7.26 and 13.64 (including the area where the crash occurred). Rumble strips (8 inches long and 6 inches wide) were installed at the same location as the painted centerline, and new pavement markings were applied. The most recent surface treatment of this segment of SR-12 occurred on August 19, 2019, with the application of a chip seal.[21] The centerline was also repainted on this date. The turn lane and fog lines were painted on September 19, 2019, the day before the crash, and the turn lane arrows were scheduled to be painted in early November 2019. Although the 2019 chip seal was applied over the rumble strips, they still provided auditory and vibratory feedback. The pavement markings conformed to MUTCD guidance (FHWA 2009).

1.5.3 Postcrash Testing and Repair

After the crash, on September 27, 2019, the Utah Highway Patrol conducted five vehicle deceleration tests using a passenger vehicle in the eastbound lanes of SR-12 at the crash location. The overall average coefficient of friction for the roadway-tire interface was measured to be about

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[17] See FHWA Technical Advisory T 5040.39. Shoulder and Edge Line Rumble Strips, accessed March 16, 2021.

[18] See UDOT 06C-17, "Use of Rumble Strips," revised April 26, 2007.

[19] *Clear zone* is defined as the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear run-out area. The desired width depends on traffic volumes and speeds, and on the roadside geometry (AASHTO 2011).

[20] A *clear zone side-slope* is commonly expressed as a ratio of the horizontal distance over which 1 foot of vertical change occurs. For example, a side-slope of 4:1 would represent a horizontal distance of 4 feet for every 1-foot change in elevation. Recoverable slopes are 4:1 or flatter, slopes between 4:1 and 3:1 are generally considered nonrecoverable, and slopes steeper than 3:1 are considered to be critical slopes (slopes on which an errant vehicle has a higher propensity to overturn) (AASHTO 2011).

[21] *Chip sealing* is a common pavement maintenance practice in which a thin layer of heated asphalt emulsion is sprayed on the road surface, followed by the spreading of small pieces of aggregate (known as chips). The chips are then compacted for maximum adherence to the asphalt, and any excess aggregate is swept from the road surface.

0.89.[22] On October 2, 2019, UDOT performed friction tests on SR-12 in the vicinity of the crash.[23] Adjusted skid numbers for the east- and westbound lanes for the area of mileposts 9–12 ranged from 37.3 to 70.4.[24] The guardrail was replaced on November 14, 2019. On January 22, 2020, UDOT repaired the edge of the asphalt-paved shoulder on eastbound SR-12 that had been damaged by contact from the crash bus; UDOT also regraded the gravel shoulder. This work eliminated the pavement edge drop-off.

1.5.4 Traffic Volume and Crash History

According to UDOT, in 2018, the annual average daily traffic for SR-12 in the vicinity of the crash was 2,320 vehicles. Cars accounted for 78 percent of the traffic, single-unit trucks for 14 percent, and combination trucks for 8 percent.[25]

Police-reported crash data for the 10-year period 2009–2018 show four crashes in the curved stretch of the road between milepost 10.15 and milepost 10.56. Two of the crashes were rear-end collisions that caused minor injuries; the other two crashes involved vehicle collisions with animals, one of which resulted in a possible injury to a vehicle occupant and one that caused no injuries. None of the collisions involved commercial vehicles, such as heavy trucks or buses, and none involved vehicles running off the roadway.

1.6 Driver Information

1.6.1 Licensing and Experience

The bus driver was a 60-year-old male. He held a class B California commercial driver's license (CDL) with a passenger endorsement and was restricted to driving commercial vehicles with automatic transmissions; he was required to wear corrective lenses.[26] He had completed CDL

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[22] The *coefficient of friction* is the ratio of the force required to move two sliding surfaces past one another to the force holding the two surfaces together. In this case, it is the ratio of the stopping tire moving over the surface of the roadway to gravity, which is the force holding the tire on the roadway. According to published data, the coefficient of friction for a decelerating passenger car on a newly paved, dry, asphalt surface will typically range between 0.65 and 1.00 (Fricke 2000 and Limpert 1994).

[23] These tests were conducted in accordance with the methods established by the American Society for Testing and Materials (ASTM) standard E274, "Standard Test Method for Skid Resistance of Paved Surfaces Using a Full Scale Tire," using calibrated equipment.

[24] A *skid number* (also referred to as a friction number) represents the frictional properties of the pavement. These numbers are used to evaluate the skid resistance of the pavement relative to other pavements and/or to evaluate the change of the pavement's skid resistance over time. The average skid number for each test was adjusted to reflect the equivalent skid number at a test speed of 40 mph. As indicated in the *Utah Department of Transportation Pavement Management Manual* (accessed March 16, 2021), surface friction values are categorized using the following condition ratings: values greater than 45 are considered sufficient, values between 35 and 45 are approaching the need for further evaluation, and values below 35 need further evaluation. Surface friction numbers from a roadway that has been chip-sealed will often be lower than friction numbers for a newly paved roadway.

[25] Buses are included in the single-unit truck category.

[26] The bus driver's CDL was issued in June 2016 and had a July 2020 expiration date.

training in June 2016. Neither the Commercial Driver License Information System nor the California Department of Motor Vehicles listed any violations for the driver.[27]

The driver began employment with America Shengjia on September 11, 2019, and he had 2 1/2 years of experience driving buses while employed by other carriers—specifically, Dragon Coach Lines and Sun Cruise.[28] The crash trip was his first driving for America Shengjia; however, he had driven to Bryce Canyon on nine previous trips while employed by Dragon Coach Lines and Sun Cruise. The driver said that, in his previous employment, he had driven buses similar to, but larger than, the bus involved in the crash.

1.6.2 Medical Certification

The bus driver's US Department of Transportation (DOT) medical certificate, which was issued in October 2017 and was valid for 2 years, did not reveal any medical conditions or required medications. His vision and hearing met Federal Motor Carrier Safety Regulation 391.41 requirements. During his postcrash interview with NTSB investigators, the driver reported his health as good and said that he was not taking any medications.

1.6.3 Toxicology

Following the crash, the driver provided a blood sample to the Utah Highway Patrol.[29] Analysis of the sample was negative for alcohol, major drugs of abuse, and specific prescription and over-the-counter drugs.[30] Preemployment drug and alcohol testing of the driver conducted on September 10, 2019, was negative. Preemployment and random drug tests with both previous employers were negative. The driver told investigators that he had never taken illicit drugs and that he had not drunk alcohol in the week before the crash.

1.6.4 Sleep/Work History

The driver's sleep opportunity/work history was captured from electronic log data, cell phone records, the driver's postcrash interview, and the tour itinerary; it is depicted in figure 13. The driver told investigators that he had no problems or issues with obtaining sleep. The night before the crash, the driver had 7 hours, 38 minutes available for sleep. The driver had a regular sleep schedule and had the opportunity to obtain 7.5–9 hours of sleep in each of the four nights

[27] As a result of the crash, the driver was cited by the Utah Highway Patrol for failure to maintain his lane.

[28] The driver's application with America Shengjia indicated that, from January 2017 to August 2019, he had been employed as a bus driver by two carriers that had the same principal.

[29] Due to the remote location of the crash, the carrier did not conduct postcrash toxicology testing as required by 49 *CFR* 382.303. However, the carrier was not cited for this failure because the driver provided a blood sample for the Utah Highway Patrol.

[30] The testing checked for ethanol, acetone, isopropanol, methanol, amphetamine, methamphetamine, MDA, MDMA, cocaine, benzoylecgonine, morphine, alprazolam, α-OH alprazolam, amitriptyline, butalbital, carbamazepine, carisoprodol, chlorpheniramine, chlordiazepoxide, clonazepam, 7-aminoclonazepam, codeine, cyclobenzaprine, dextromethorphan, diazepam, diphenhydramine, doxylamine, fentanyl, norfentanyl, hydrocodone, lorazepam, meperidine, meprobamate, methadone, midazolam, nordiazepam, nortriptyline, oxazepam, oxycodone, phenobarbital, phenytoin, propoxyphene, temazepam, tramadol, trazodone, zaleplon, and zolpidem.

preceding the crash. On the morning of the crash, he had been driving for 3 hours, 16 minutes and had been on duty for 3 hours, 45 minutes. A review of the driver's hours of service did not show any 10-hour, 15-hour, or 70-hour hours-of-service (HOS) violations.[31]

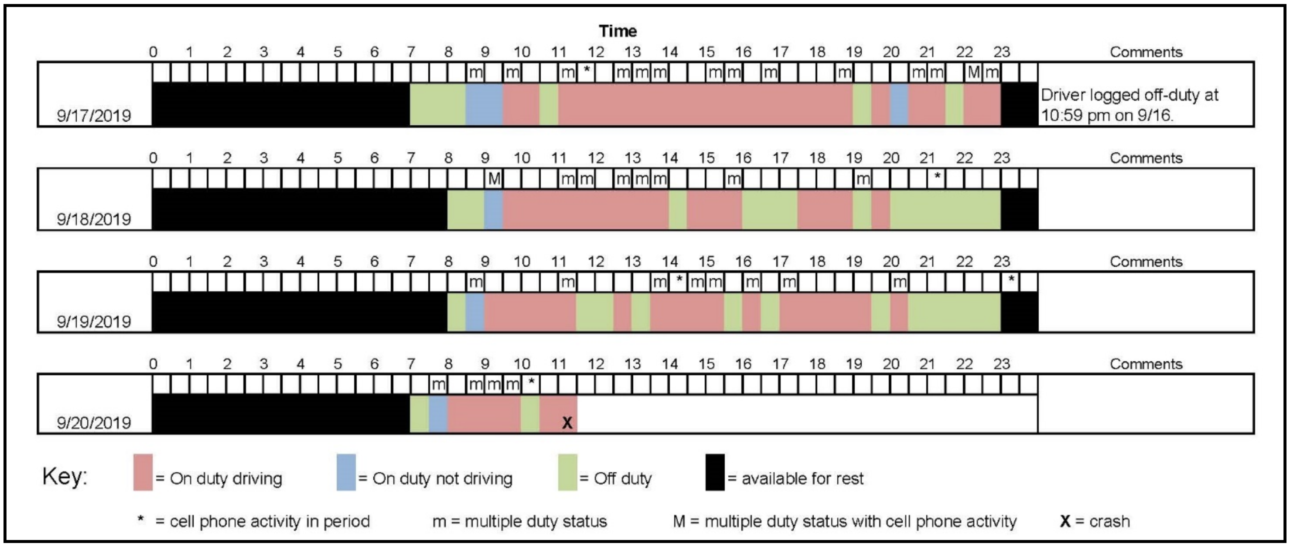

Figure 13. Bus driver sleep and work history.

1.6.5 Distraction

The driver told investigators that he was not using his cell phone at the time of the crash, and cell phone records indicate that its last activity was at 10:15 a.m., which coincides with an off-duty period for the driver. The driver said that he was not aware of any other communication devices on the bus and that he did not use a global positioning system device. A visual examination of the crash site, under conditions similar to those of the crash, did not show any unusual or distracting features or objects in the environment. When asked by investigators, the driver indicated that he did not have any issues with glare or illumination from the sun.

The driver said that he did not know what the passengers were doing at the time of the crash because he was concentrating on driving; he indicated that he was not distracted by anything happening on the bus.[32] During his interview, investigators asked the driver about major life events such as marriage, death, significant illness, or major monetary expense. The driver said that he had not experienced any significant life events in the past month.

[31] Since December 18, 2017, all carriers and drivers subject to regulations have been required to use electronic logging devices. (There were some exceptions for automatic on-board recording devices until December 16, 2019.) The bus driver used an electronic logging device.

[32] The tour had a full-time tour guide on board, who provided information to the passengers while the bus driver was driving the bus.

1.6.6 Driver's Account of Crash

The driver told NTSB investigators that the trip had been normal until the crash, although he noted that he had had trouble starting the bus at the last stop before the crash. He said he spoke with his boss (via cell phone), who told him to hit the starter, which he did, and the bus started. The driver said that the road felt different from how it seemed on his previous trip; he described it as newly paved and slippery. He stated that he did not apply any steering input; he also said that he did not remember the bus wheels going off the edge of the road or the bus going onto its side. He recalled the bus tilting to the left, then right, then left again, and he said that the bus was not in his control. He said that he exited the bus after the crash to assist the passengers. The driver said that, during the safety briefing, the tour guide had told the passengers to wear their seat belts. He also said that he was wearing his lap/shoulder belt at the time of the crash.

1.7 Motor Carrier Operations and Regulatory Oversight

1.7.1 America Shengjia

The motor carrier America Shengjia, Inc., was registered with the Federal Motor Carrier Safety Administration (FMCSA) as an interstate passenger carrier on August 6, 2015.[33] The motor carrier provided transportation services to tour companies in the states of Nevada, Utah, Idaho, Montana, and California. At the time of the crash, America Shengjia operated two vehicles and employed two drivers. Postcrash, on January 14, 2020, America Shengjia filed an out-of-business notification.[34]

1.7.2 Federal Oversight

America Shengjia passed a new entrant safety audit on May 4, 2016. The carrier did not have any alerts in the FMCSA Safety Management System. Following the crash, the FMCSA conducted a compliance review on the carrier. America Shengjia received a satisfactory rating, although inspectors noted 10 violations.[35]

1.7.3 State Oversight

In California, responsibility for motor carrier oversight is shared among several state entities. The California Highway Patrol (CHP) is the designated law enforcement agency,

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[33] To register with the FMCSA, the carrier completes a motor carrier identification form (MCS-150).

[34] America Shengjia filed an MCS-150 form to notify the FMCSA that it was going out of business. Motor carriers are required to update their MCS-150s every 2 years, as well as any time there is a business change.

[35] (a) The violations were as follows: not ensuring each driver has an equal chance of random alcohol and controlled substance testing [382.305(i)(2)], failing to provide to employees a written drug policy [382.601(b)], no annual list of traffic violations [391.11(b)(6)], incomplete or no employment application [391.21(a)], failing to investigate a driver's background [391.23(a)], failing to investigate a driver's drug and alcohol history for the previous 3 years [391.23(e)(1)], failing to review the driving record of each driver to determine whether that driver meets minimum requirements for safe driving or is disqualified to drive [391.25(b)], failing to ensure that the driver's electronic logging device record is accurate [395.30(a)], failing to require a driver to prepare a record-of-duty status [395.8(a)(1)], and failing to keep a record of tests conducted on pushout windows [396.3(b)(4)].

responsible for compliance with the *California Vehicle Code* relating to the safe operation of commercial motor vehicles. It is authorized to conduct terminal inspections of motor carriers.[36] The California Public Utilities Commission has regulatory and safety oversight of for-hire passenger carriers. It ensures that carriers are properly licensed and that any complaints lodged against the carrier are investigated. It also ensures that a carrier has the proper level of insurance and monitors its drivers. The California Department of Motor Vehicles administers the Employer Pull Notice Program and tracks driver violations of the *California Vehicle Code*.[37]

America Shengjia was registered with the CHP and had intrastate operating authority. The CHP conducted the most recent precrash terminal inspection of the carrier on January 3, 2019; it resulted in a satisfactory rating. The carrier's four previous terminal inspections were also satisfactory. The California Public Utilities Commission reported no record of complaints or enforcement actions against America Shengjia. The carrier held a class A charter-party certificate valid until February 19, 2022.[38] America Shengjia had enrolled the bus driver in the Employer Pull Notice Program on September 11, 2019.

1.8 Weather and Astronomical Data

Investigators obtained weather data for September 20, 2019, from Bryce Canyon Airport, about 3 miles east of the accident site. According to the Automated Surface Observation System, at 10:53 a.m., weather conditions included wind from the northwest at 7 mph, visibility unrestricted at 10 statute miles or more, clear skies, a temperature of 53ºF, and a dew point temperature of 24ºF, with relative humidity of 32 percent.

According to the National Oceanic and Atmospheric Administration Solar Calculator, for the crash location on September 20, 2019, apparent sunrise was at 7:15 a.m. and apparent sunset was at 7:29 p.m. At 11:26 a.m., the sun was at an azimuth of 136.97 degrees from true north and an elevation of 44.61 degrees, which positioned the sun ahead of and slightly to the right of the driver's view at the time of the crash.

[36] These inspections are authorized by division 14.8 of the *California Vehicle Code*. Terminal inspections are similar to federal safety audits and compliance reviews.

[37] The Employer Pull Notice Program notifies employers, including self-employed drivers, when a driver is convicted of a violation of the *California Vehicle Code*, has an accident posted to his or her driving record, is classified as a negligent operator, or has his or her license suspended or revoked. Employers are required to periodically obtain driver reports and review them.

[38] A carrier with a class A charter-party certificate may conduct chartered service, operate vehicles of any seating capacity, operate vehicles from any point to any point within California, conduct round-trip sightseeing trips, and charge individual fares in doing so. Except for round-trip sightseeing, charges must be based on vehicle mileage, time of use, or a combination of both, and certificates may be transferred. (See California Public Utilities Commission Charter Permits, accessed March 16, 2021.)

1.9 Additional Information

1.9.1 Moving Ahead for Progress in the 21st Century Act

In July 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law as a multiyear transportation authorization bill.[39] MAP-21 contains subtitle G—the Motorcoach Enhanced Safety Act of 2012—which mandates motorcoach rulemaking and research projects on crashworthiness and crash avoidance. In its definition of "motorcoach," it refers to an "over-the-road" bus, which is defined as a "bus characterized by an elevated passenger deck located over a baggage compartment."[40] The National Highway Traffic Safety Administration (NHTSA) considered the bus involved in this crash an over-the-road bus because it had an elevated passenger deck above the baggage compartment.[41]

In 2013, in response to MAP-21 (and NTSB safety recommendations), NHTSA published a final rule (effective date November 28, 2016) amending Federal Motor Vehicle Safety Standard (FMVSS) 208 on occupant protection to require lap/shoulder belts for each passenger seating position in all new over-the-road buses and in new buses other than over-the-road buses with GVWRs greater than 26,000 pounds.[42] The final rule's compliance date for multistage buses was 1 year later, November 28, 2017. The bus involved in the crash was built in multiple stages, with the final stage completed in February 2017. It was not required to be equipped with passenger lap/shoulder belts (49 *CFR* 571.8[b]).

In August 2014, in response to MAP-21 (and NTSB safety recommendations), NHTSA published a notice of proposed rulemaking (NPRM) to improve the rollover structural integrity of all new over-the-road buses and of new buses other than over-the-road buses with GVWRs greater than 26,000 pounds.[43] In May 2016, NHTSA published another NPRM, this one addressing the installation of advanced window glazing in all new over-the-road buses and in new buses other than over-the-road buses with GVWRs greater than 26,000 pounds.[44] In its comments on the rulemaking actions, the NTSB expressed disappointment that these two proposed rules did not

[39] For more information on MAP-21, see Public Law 112–141, accessed March 16, 2021.

[40] See section 3038 of Public Law 105–178, 49 *United States Code* 5310 note (Transportation Equity Act for the 21st Century).

[41] This classification is reflected in an e-mail from NHTSA to NTSB staff, dated July 20, 2020. The e-mail is available in the NTSB docket for this investigation (which can be found by accessing the NTSB Docket Search Page and searching for case number HWY19MH012) as "Survival Factors Attachment—E-mail Response on Bus Classification."

[42] (a) For more information, see FMVSS 208 final rule, accessed March 16, 2021. (b) Details concerning the seat belt requirements for over-the-road buses are in FMVSS 208.

[43] See *Federal Motor Vehicle Safety Standards, "*Bus Rollover Structural Integrity, Motorcoach Safety Plan," proposed rule, August 6, 2014 (79 *Federal Register* 46090, docket no. NHTSA-2014-0085).

[44] See *Federal Motor Vehicle Safety Standards*, "Bus Emergency Exits and Window Retention and Release, Anti-Ejection Glazing for Bus Portals," proposed rule, May 6, 2016 (81 *Federal Register* 27904, docket no. NHTSA-2016-0052).

include all medium-size buses and urged NHTSA to expand the rulemakings to address them.[45] No further action has taken place on these rulemakings.[46]

1.9.2 Fatality Analysis Reporting System Data Analysis

The Fatality Analysis Reporting System (FARS) is a NHTSA-maintained census of fatal traffic crashes in the 50 states, the District of Columbia, and Puerto Rico.[47] NTSB investigators analyzed FARS data on bus crash characteristics for crashes occurring during the years 2010–2018. The analysis focused on the data for the bus types most comparable to the bus involved in this crash: specifically, buses with GVWRs between 10,000 and 26,000 pounds. During this period, 2,232 buses were involved in fatal crashes, resulting in 435 fatalities to bus occupants. Basic findings are summarized in table 3. Of the 95 buses involved in rollover crashes, 40 had GVWRs between 10,000 and 26,000 pounds.

Table 3. Bus crash data (FARS 2010–2018).

Type of Bus	Buses Involved in Fatal Crashes[a]	Buses Involved in Fatal Crashes with GVWR 10,001–26,000 lbs.	Buses Involved in Fatal Rollover Crashes (Total Buses *Versus* Buses with GVWR 10,001–26,000 lbs.)	Fatalities to Bus Occupants (Total Fatalities *Versus* Fatalities in Buses with GVWR 10,001–26,000 lbs.)
School	866	212	30/8	99/30
Cross country/intercity	266	31	28/7	146/24
Transit	764	89	6/2	46/3
Van-based (GVWR > 10,000 lbs.)	169	165	19/19	66/65
Other type	132	43	10/4	69/18
Unknown type	35	8	2/0	9/1
TOTAL	2,232	548	95/40	435/141

[a] Note: The fatality is not necessarily a bus occupant. It may be an occupant of another vehicle or a pedestrian involved in the crash.

[45] To view the NTSB's comment letters on these rulemaking actions, see NTSB 2014 comments on the structural integrity rule and NTSB 2016 comments on the glazing rule, both accessed March 16, 2021.

[46] In late 2020, NHTSA issued its Unified Agenda of Regulatory Actions (accessed March 16, 2021), which indicated that the agency intended to issue a final rule in early 2021 on motorcoach rollover structural integrity. As of the date of this report (May 10, 2021), NHTSA had not taken such action.

[47] To be included in FARS, a crash must involve a motor vehicle traveling on a trafficway customarily open to the public and must result in the death of an occupant of a vehicle or a nonoccupant within 30 days of the crash.

2 Analysis

2.1 Introduction

The medium-size, over-the-road bus was traveling east on SR-12 near Bryce Canyon City, Utah, occupied by a driver and 30 passengers. Near mile marker 10.4, at a vehicle-recorded speed of 64 mph, the bus's right wheels departed the right edge of the roadway. The driver steered left to return the bus to the roadway, redirecting the bus into the westbound travel lane. The driver then steered sharply to the right, causing the bus to roll 90 degrees (or a quarter turn) onto its left side. The bus slid on its left side about 85 feet, until its roof struck the guardrail end treatment along the westbound side of the roadway and rolled over the guardrail, coming to rest on its wheels after one complete roll. At final rest, the bus straddled the damaged guardrail, with its front end partially blocking the westbound travel lane of SR-12. No other vehicles were involved in the crash. As a result of the crash, 4 passengers were fatally injured, 17 sustained serious injuries, and 9 sustained minor injuries.

The analysis portion of this report first discusses factors that could be excluded because they were not causal to the crash or did not contribute to the severity of its outcome. Then, the analysis addresses the bus driver's actions as the bus departed from the roadway, returned to it, and rolled over (section 2.2). The following safety issues are also discussed in the analysis:

- Lack of requirements for vehicle technology to prevent medium-size bus road departures and rollovers (section 2.3).
- Lack of occupant protection and crashworthiness standards for medium-size buses (section 2.4).

As a result of its analysis, the NTSB established that the following factors did not cause or contribute to the crash:

- **Mechanical Operation of the Vehicle**—Postcrash inspection did not reveal any preexisting mechanical defects or deficiencies in the engine, tires, steering, braking, suspension, or electrical systems. Maintenance records detailed regular service intervals and safety inspections.
- **Roadway Design and Condition**—SR-12 in the area of the crash had been repaved, and the lane lines had been painted on the pavement shortly before the crash. The regulatory signs, warning signs, and pavement markings conformed to MUTCD guidance. The roadway surface was dry; however, the bus driver told investigators that he thought that the roadway felt slippery. Following the crash, surface friction tests conducted by UDOT and the Utah Highway Patrol found that the available surface friction was consistent with friction results expected on new or newly repaved roadways. The discontinuation of shoulder rumble strips in this area of SR-12, to accommodate the turn lanes and rest area entrance, conformed to available design guidance and was appropriate for this portion of the multi-use roadway, which is also a designated bicycle route.

- **Motor Carrier Operations and Oversight**—The motor carrier America Shengjia was properly registered with the FMCSA, the California Public Utilities Commission, the California Department of Motor Vehicles, and the CHP. The carrier had fulfilled the FMCSA new entrant program. America Shengjia had received a satisfactory rating in a terminal inspection conducted by the CHP in January 2019 and a satisfactory rating in the postcrash compliance review conducted by the FMCSA.

- **Licensing and Experience**—The driver was licensed for the vehicle he was operating and held the proper endorsements. He had 2 years of experience driving buses, including buses similar to the crash vehicle. Although this was the driver's first trip for America Shengjia, he had driven this route for a previous employer, giving him familiarity with the crash location.

- **Alcohol and Drugs**—The driver said that he had never used illicit drugs and that he did not drink alcohol in the week before the crash. Postcrash toxicological testing conducted at the request of the Utah State Police was negative for alcohol, major drugs of abuse, and all the prescription and over-the-counter drugs included in the testing.

- **Fatigue**—The driver had opportunity for 7.5–9 hours of rest in each of the four nights preceding the crash. The driver reported that he did not have any history of sleep issues, and his sleep patterns were regular and oriented to normal circadian rhythms. In compliance with federal regulations, the driver's HOS records were properly recorded using an electronic logging device, and the driver was within the HOS limits for passenger carriers.

- **Distraction**—Cell phone records showed that the driver was not making a call or texting at or near the time of the crash. The driver indicated that he was not distracted by bus occupants or by anything inside the vehicle. Investigators identified no external distractions at the location where the crash occurred.

- **Medical Issues**—The driver said that he had no chronic medical conditions and was not taking any medications regularly or on the day of the crash. The driver's medical certificate did not reveal any medical conditions or required medications. According to his medical certification exam, the driver's vision and hearing met regulatory standards.

- **Weather/Illumination**—Data from a nearby weather station indicated no precipitation at or near the crash site at the time of the crash. The road surface was dry, and the crash occurred during daylight hours. Although the sun was positioned ahead of and slightly to the right of the driver's view at the time of the crash, the driver indicated that he had no issues with illumination or glare.

The NTSB concludes that none of the following were factors in this crash: (1) mechanical operation of the bus; (2) design, markings, signage, or friction characteristics of the highway; (3) motor carrier operations or state or federal oversight of the motor carrier; (4) driver experience, licensing, alcohol or drug use, fatigue, distraction, or medical issues; and (5) weather or illumination.

Twelve local and state emergency services responded to the scene of the crash. The first unit arrived at the scene within 9 minutes of being notified of the crash. A volunteer firefighter/emergency medical technician who spoke Mandarin was beneficial in assisting the passengers during triage. Twenty-six passengers were transported from the crash scene within 2 hours of the crash. The NTSB concludes that the emergency response and the transportation of the injured passengers were timely and adequate.

2.2 Bus Driver Actions

The first event in the crash sequence was the bus's departure from the roadway. About 50 percent of traffic fatalities result from roadway departure crashes.[48] Run-off-the-road crashes account for about 70 percent of fatal single-vehicle crashes (Liu and Subramanian 2009).[49] Most run-off-the-road crashes stem from driver-related factors, including internal distractions, being asleep, physical impairment, overcompensation, driving too fast for a curve, and inattention (Liu and Ye 2011, Starnes 2006).

The NTSB determined that the bus driver was familiar with SR-12, properly licensed, and medically qualified; he had an opportunity to receive adequate sleep; he was not distracted by a cell phone, life stressors, passengers, or environmental factors; and the sun did not affect his vision. Although research suggests that driver distraction and inattentiveness are associated with run-off-the-road crashes, there is no evidence to suggest that the bus driver was distracted or inattentive.

The section of SR-12 where the crash occurred had been recently repaved, and the bus driver described the road surface as different from his other trips; he said it felt slippery. However, investigators found no roadway anomalies or other factors that would have reduced pavement friction. Friction test results indicated that the available surface friction was adequate and similar to what would be expected on a new or newly repaved roadway. The NTSB concludes that the bus driver failed to keep the bus within the travel lane for undetermined reasons, and the bus's right-side tires left the roadway.

Following the bus's departure from the road, a sharp redirection of the bus back to the roadway is evidenced by tire marks across the roadway toward the left. Although the driver denied providing any steering input, the short distance between where the bus departed the roadway and where it returned indicates steering input to the left. Research has shown that when drivers are faced with a hazard, their response involves braking, steering, and sometimes a combination of both (Lechner and Malaterre 1991, Lerner 1993, McGehee and others 1999, Hancock and De Ridder 2003). The driver's steering maneuver to the left allowed him to return the bus to the

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[48] (a) A *roadway departure crash* is defined as a crash that occurs after a vehicle crosses an edge line or a centerline, or otherwise leaves the traveled way. (b) See [FHWA Roadway Departure Safety](), accessed March 16, 2021.

[49] (a) The term *run-off-the-road crash* refers to a vehicle in transport that leaves the travel lane and encroaches onto the shoulder, median, roadside, parking lane, gore, or a separator and hits one or more natural or artificial objects. (b) The 2009 report is based on FARS data and includes passenger cars, vans, pickup trucks, and utility vehicles.

roadway, but it sent the vehicle into the opposing lane of traffic. The driver's next response was to steer sharply back to the right, causing the bus to become unstable.

When a driver inputs sharp steering and then abruptly reverses the direction of that steering, the vehicle may reach its limits of traction on the roadway and, for larger vehicles with higher centers of gravity, such as buses, the vehicle may begin to roll. The driver's steering input in this crash was an overcontrol of the vehicle and resulted in the bus's losing roadway traction, sliding sideways, and then overturning onto its left side. The NTSB concludes that the driver responded to the bus's departure from the roadway first by overcorrecting to the left to reenter the roadway, and then by overcorrecting to the right, after the bus had begun to enter the opposing travel lane; these overcorrections caused the bus to become unstable and to roll over.

2.3 Technologies to Prevent Bus Rollovers and Roadway Departures

This section begins with a discussion of technologies that could have prevented the most catastrophic event of this crash—the rollover. ESC systems are designed to prevent rollover crashes (section 2.3.1). Then, it discusses technologies that could have prevented the initiating event of the crash sequence—the lane departure. LDP and LDW systems are designed to prevent lane departure (section 2.3.2).

2.3.1 Electronic Stability Control Systems

The bus driver's overcorrection inputs to the left and then back to the right led to an unstable condition in the bus and, ultimately, to its rolling over. ESC systems are designed to reduce untripped rollovers and to mitigate severe under- and overcorrection steering actions that lead to loss of vehicle control, such as occurred with the bus in this crash.[50] Using information from the engine and sensors in the antilock braking and steering systems, ESC systems monitor wheel speed, vehicle speed, lateral acceleration, vehicle yaw, and driver input. If there is an unstable vehicle condition, the ESC system automatically brakes individual wheels (or a combination of wheels) to help stabilize or slow the vehicle. An ESC system maximizes the possibility of keeping the vehicle under control and on the road during extreme maneuvers. By maintaining vehicle control during extreme or evasive maneuvers, ESC systems help to prevent heavy vehicle rollover crashes. Estimates suggest that up to 31,000 large truck crashes per year are prevented by ESC systems (Jermakian 2012).

The NTSB has previously recommended that NHTSA require ESC systems on newly manufactured commercial vehicles. Following its investigation of a 2005 crash that occurred when a truck-tractor semitrailer rolled over and a motorcoach collided with the overturned truck near Osseo, Wisconsin, the NTSB issued Safety Recommendation H-08-15, which asked NHTSA to determine whether equipping commercial vehicles with collision warning systems with active braking and ESC systems would reduce commercial motor vehicle accidents and, if they were found effective, to require their use on commercial vehicles (NTSB 2008). Although NHTSA's

[50] (a) An *untripped rollover* is a rollover event that is not induced or assisted by an impact or other contact with a physical feature; an untripped rollover usually occurs during a collision avoidance maneuver. (b) See *Federal Motor Vehicle Safety Standards*, "Electronic Stability Control Systems for Heavy Vehicles," final rule, June 23, 2015 (80 *Federal Register* 36050, docket no. NHTSA-2015-0056).

research indicated that automatic emergency braking and ESC systems would reduce commercial motor vehicle crashes, NHTSA did not take regulatory action, which delayed deployment of collision avoidance technologies in commercial vehicles. Consequently, the NTSB classified Safety Recommendation H-08-15 "Closed—Unacceptable Action" in its 2015 special investigation report on the use of forward collision avoidance systems to prevent and mitigate rear-end crashes (NTSB 2015a).

As a result of its investigation of a medium-size bus loss of control and rollover crash near Dolan Springs, Arizona, on January 30, 2009 (NTSB 2010), the NTSB issued Safety Recommendations H-10-5 and -6 to NHTSA, asking that the agency develop performance standards for stability control systems applicable to newly manufactured buses with GVWRs above 10,000 pounds (Safety Recommendation H-10-5) and, once the performance standards were developed, require the installation of stability control systems in all newly manufactured buses in which the technology could have a safety benefit (Safety Recommendation H-10-6). In the NTSB's report of an investigation into the rollover of a cargo tank semitrailer carrying liquefied petroleum gas and subsequent fire in Indianapolis, Indiana, the NTSB classified Safety Recommendations H-10-5 and -6 "Closed—Superseded" by Safety Recommendations H-11-7 and -8 to NHTSA, which read as follows (NTSB 2011):

H-11-7

> Develop stability control system performance standards for all commercial motor vehicles and buses with a gross vehicle weight rating greater than 10,000 pounds, regardless of whether the vehicles are equipped with a hydraulic or a pneumatic brake system.

H-11-8

> Once the performance standards from Safety Recommendation H-11-7 have been developed, require the installation of stability control systems on all newly manufactured commercial vehicles with a gross vehicle weight rating greater than 10,000 pounds.

In May 2012, NHTSA published a proposed rule to establish FMVSS 136 to require ESC systems on truck-tractors and certain buses with GVWRs over 26,000 pounds.[51] In its August 9, 2012, comments on the 2012 NPRM, the NTSB expressed its concern that, because FMVSS 126 required ESC systems on light vehicles (those with GVWRs less than 10,000 pounds) and FMVSS 136 extended ESC requirements to heavy vehicles (those with GVWRs greater than 26,000 pounds), NHTSA had created a gap in ESC requirements for those vehicles with GVWRs between 10,000 and 26,000 pounds.[52] The NTSB pointed out that the bus involved in the Dolan Springs crash had a GVWR of 19,500 pounds and would not have been covered by the ESC requirement. In June 2015, NHTSA issued a final rule establishing FMVSS 136 and justified the exclusion of commercial vehicles with GVWRs between 10,000 and 26,000 pounds in its

[51] See proposed rule NHTSA-2012-0065-0001, accessed March 16, 2021.

[52] See the NTSB comment on proposed rule NHTSA-2012-0065-0015, accessed March 16, 2021.

rulemaking by stating that it had begun research on the safety benefits and performance criteria of ESC systems on single-unit trucks and that the study included medium-size buses.[53]

After the FMVSS 136 final rule was published, NHTSA completed test track research of single-unit trucks equipped with ESC systems (Elsasser, Davis, and Rao 2015). In general, ESC systems improved the stability of the trucks in lateral stability maneuvers. Additionally, through an e-mail dated November 2, 2020, a NHTSA staffer informed the NTSB that the agency has initiated two studies assessing medium-duty truck crashes: one study is examining precrash scenarios and their relationship to crash avoidance technology, and the other is based on the analysis of 200 medium-duty fatal truck crashes. The studies are in progress, and NHTSA expects to complete them by the end of 2021.[54]

In a letter to NHTSA dated November 13, 2017, the NTSB recognized that NHTSA had issued a final rule establishing FMVSS 136 but noted that the rulemaking was limited to truck-tractors and certain buses with GVWRs over 26,000 pounds. The NTSB asked NHTSA for an update on its planned actions and a timeline for addressing stability control in the remaining vehicle categories. In the November 13, 2017, letter to NHTSA, the NTSB classified Safety Recommendations H-11-7 and -8 "Open—Unacceptable Response."

The NTSB reiterated Safety Recommendations H-11-7 and -8 in the 2018 special investigation report on school bus safety issues, which included the investigation of a school bus crash in Chattanooga, Tennessee, in which the driver lost control of a school bus (NTSB 2018a). In that report, the NTSB concluded that, had the vehicle instability that was caused by the Chattanooga bus driver's excessive speed and steering input occurred in a newly manufactured school bus equipped with an ESC system, the technology could have assisted the driver in maintaining vehicle control and mitigated the severity of the crash by reducing the vehicle's speed. Under FMVSS 136, school buses are excluded from the requirements; however, ESC systems are becoming available for many school bus models (Blue 2018).

On March 4, 2019, NHTSA replied to the reiteration of Safety Recommendations H-11-7 and -8 in the special investigation report (NTSB 2018a), indicating that when it issued the June 2015 final rule establishing FMVSS 136, it had included buses with hydraulic brakes in the final rule to spur the development of ESC systems for other hydraulic-braking vehicles, including trucks with GVWRs greater than 10,000 pounds but less than 26,000 pounds. NHTSA also said that school buses were excluded from the ESC final rule because crash statistics indicated that most school bus crashes are not rollover or loss-of-control crashes. Finally, NHTSA noted that, despite the exclusion of these vehicles from its June 2015 final rule, several manufacturers offer ESC systems as optional equipment for school buses and heavy vehicles.

In a letter to NHTSA dated July 12, 2019, the NTSB again acknowledged NHTSA's progress toward addressing heavy vehicle stability control in its June 2015 final rule; however, the

[53] See *Federal Motor Vehicle Safety Standards*, "Electronic Stability Control Systems for Heavy Vehicles," final rule, June 23, 2015 (80 *Federal Register* 36050, docket no. NHTSA-2015-0056).

[54] The November 2, 2020, e-mail is available in the NTSB docket for this investigation, which can be found by accessing the NTSB Docket Search Page and searching for case number HWY19MH012. The e-mail is listed as "NHTSA e-mail on FMVSS 136."

NTSB noted its disappointment that NHTSA had excluded other vehicles, including school buses, from the rule. The NTSB urged NHTSA to extend the mandate, particularly because a stability control system is an important component of effective automatic emergency braking and collision avoidance systems. The NTSB also indicated that ESC technology had changed rapidly and was widely available and in use. Safety Recommendations H-11-7 and -8 remained classified "Open—Unacceptable Response."

Vehicles with GVWRs between 10,000 and 26,000 pounds comprise a sizeable portion of the bus population, and the popularity of buses of this size is increasing. According to Mid-Size Bus Manufacturers Association data, the production volume of medium-size buses was nearly 16,000 units in 2015, compared with about 10,000 units in 2002 (NTSB 2018b).[55] For comparison, 2,141 motorcoaches were sold for the North American market in 2015.[56]

Although they are neither required nor standard on vehicles with GVWRs between 10,000 and 26,000 pounds, the availability of ESC systems for such vehicles has increased (Bendix 2017). ESC systems are readily available for all newly manufactured air-braked commercial vehicles, including the crash-involved bus, even though it was manufactured in stages.[57] When a body is added to a chassis that has been originally set up with ESC, and the chassis is not modified, the ESC systems will function normally.[58] Freightliner offered ESC as an option on the chassis of the crash-involved bus when it was manufactured.

ESC systems are critical components of vehicle safety not only because they can prevent rollover crashes but also because they are integral to other safety technologies. For example, LDP systems (see following section 2.3.2) use the vehicle's steering and braking capabilities to keep it in, or return it to, its intended lane of travel. LDP systems that depend on braking would not function properly if the vehicle were not equipped with an ESC system. FMVSS 136 includes requirements that an ESC-equipped vehicle meet objective performance requirements when subjected to specified dynamic test maneuvers. The requirements help prevent untripped rollovers, as well as mitigate under- and overcorrection steering actions that could lead to a loss of directional or steering control.

In this crash, the bus driver steered left and then abruptly right following the bus's departure from the roadway. Such sharp steering inputs are the types of maneuvers that ESC systems are designed to modulate. Had the bus been equipped with an ESC system, it could have aided the driver by reducing the risk of loss of control and rollover as he attempted to steer back onto the roadway. However, although suitable technology was available, the bus was not equipped with an ESC system, nor was it required to be. The NTSB concludes that had the bus been equipped with

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[55] See the *Medium-Size Bus Production and Sales Supplemental Information Report* in the NTSB docket for the Concan, Texas, investigation, accessed March 16, 2021. (The NTSB accident number for the Concan investigation is HWY17MH011.)

[56] See Metro Magazine 2017 Factbook, accessed March 16, 2021.

[57] According to the 2017 Bendix report, ESC systems are not widely available for large vehicles with hydraulic brakes.

[58] One major manufacturer of ESC systems, Bendix, recommends disabling its system if an ESC-equipped chassis wheelbase is shortened or extended, because there could be vehicle braking and performance issues, leading to possible loss of control.

an ESC system, the technology would have assisted the driver in maintaining control of the bus and reduced the likelihood of vehicle rollover.

When NHTSA issued the 2012 NPRM for FMVSS 136, the NTSB noted in its comments that medium-size buses are used to transport groups of people and should be held to the same, or higher, safety standards as vehicles used to transport cargo. Further, the NTSB urged NHTSA to be "as far-reaching as possible when implementing life-saving safety technology such as ESC." The NTSB maintains this position and remains concerned that buses with GVWRs between 10,000 and 26,000 pounds are not required to be equipped with ESC systems. Therefore, the NTSB concludes that the safety of buses with GVWRs between 10,000 and 26,000 pounds would be enhanced by equipping them with ESC systems. Such systems not only reduce the risk of vehicle loss of control and rollover crashes but also enable the use of other safety technologies. Therefore, the NTSB reiterates Safety Recommendations H-11-7 and -8 to NHTSA.

2.3.2 Lane Departure Prevention and Warning Systems

LDP systems use lane-monitoring technology to actively keep drivers from unintentionally drifting out of their lanes.[59] An LDP system uses the information provided by sensors to determine if a vehicle is about to move out of its lane. If the driver does not take corrective action, the LDP system steers, brakes, accelerates one or more of the wheels, or uses a combination of these actions to return the vehicle to its intended lane of travel. (It should be noted that an LDP system that uses braking to keep the vehicle within the lane would not function if the vehicle were not also equipped with an ESC system.)

While a typical LDP system alerts the driver when the vehicle begins to drift from its travel lane and then, if the driver does not respond, actively intervenes to return the vehicle to its lane, an LDW system only alerts the driver when the vehicle begins to move from the lane. An LDW system relies on the driver to respond to the warning of movement from the lane.[60] An LDW system does not intervene to take corrective action.

The foundation of both LDW and LDP systems is a camera, often located on the windshield near the rearview mirror, that recognizes painted lane markings. Faded lane markings, poor lighting conditions, glare, fog, and obstacles can affect the system's reliability, because if the camera cannot consistently detect the lane markings, the system might be unable to predict when a lane departure is imminent.

When the Bryce Canyon City crash occurred, it was daytime, the weather was clear, and the lane markings on SR-12 in the area of the crash location had recently been repainted and were in compliance with MUTCD guidance. In fact, the fog line had been painted the day before the crash, and the centerline had been repainted about 1 month earlier. Although the effect of glare on the camera system was not specifically tested and the sun was positioned ahead and slightly to the

[59] For additional information, see NHTSA webpage on Driver Assistance Technologies, accessed March 16, 2021.

[60] Most LDW systems alert the driver only when the vehicle is traveling above a specific speed (typically 35 mph) and do not alert the driver if the driver indicates an intention to change lanes by activating the turn signal. Warning signals may be auditory, visual, haptic, or provided through a combination of these modalities.

right of the driver's view, the driver did not report any issues with glare, which suggests that the camera's view of the lane marking would have been adequate. The NTSB concludes that the lane markings on SR-12 were visible and in good condition; therefore, a lane departure warning or prevention system should have been able to detect and recognize the lane markings and provide appropriate alerts or action in response to the bus's departure from the lane.

Estimates of the potential number of crashes that could be prevented by LDW and LDP systems vary widely (from as low as 5,000 to as high as 483,000 per year), but as the systems' effectiveness improves and they become more widely adopted, the potential for preventing crashes increases (Penmetsa, Hudnall, and Nambisan 2019). Although LDP systems have been proven more effective than LDW systems at preventing crashes and reducing the number of seriously injured drivers (Scanlon and others 2015), crash data simulation research has shown that both LDW and LDP systems reduce lane departure crashes. In general, LDW systems have been shown to have positive safety effects for heavy vehicles (NHTSA 2014 and 2015, Hickman and others 2013, Camden and others 2017).

Currently, neither LDP nor LDW systems are required on any vehicles, including large commercial vehicles. In 2010, as a result of the previously noted Dolan Springs, Arizona, crash investigation (NTSB 2010), the NTSB recommended, in Safety Recommendation H-10-1, that NHTSA take the following action:

<u>H-10-1</u>

> Require new commercial motor vehicles with a gross vehicle weight rating above 10,000 pounds to be equipped with lane departure warning systems.

NHTSA responded to the recommendation by indicating that its focus concerning LDW systems was on passenger vehicles and on including LDW systems in the New Car Assessment Program (NCAP), which applies to passenger, not commercial, vehicles.[61] Based on NHTSA's lack of progress on this recommendation, the NTSB classified Safety Recommendation H-10-1 "Open—Unacceptable Response" on March 30, 2015, and that is the current status of the recommendation. Despite a November 13, 2017, formal request from the NTSB for a status update, NHTSA has not provided a written response about this recommendation since December 3, 2014. Thus far, NHTSA has not required LDW systems on any vehicles.

The NTSB is aware of at least two manufacturers that offer LDP systems for commercial vehicles, Wabco and Bosch.[62] The system offered by Wabco combines a forward-looking camera and active steering to keep the vehicle in its lane. The Bosch system also uses a camera to detect lane markings and, for vehicles with electric power steering, the LDP system uses the steering system to keep the vehicle in its lane. In vehicles without electric power steering, the Bosch LDP system uses the ESC system to brake individual wheels to keep the vehicle in its lane.

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[61] NCAP uses a 5-star rating system to evaluate how well a passenger vehicle performs in frontal, side, and rollover crash tests. It also provides information about the availability of advanced safety technology for a passenger vehicle. For more information, see vehicle safety ratings, accessed March 16, 2021.

[62] For more information, see Wabco OnLane Departure System, and Bosch lane-keeping assist for heavy vehicles, both accessed March 16, 2021.

LDW and ESC systems were available options when the 2017 Freightliner bus was ordered, but neither system was purchased at that time from Freightliner. An LDP system was not an available option at that time. Today, Freightliner offers several optional driver-assist features on its medium-size buses, including an LDP system that first signals to the driver that the bus has crossed a lane marker and then, if the vehicle continues to move out of the lane, actively steers it back into the lane. Although not required, LDW systems are now standard with the Daimler Trucks North America Detroit Assurance 5.0 suite of safety systems. (Freightliner Trucks is a division of Daimler Trucks North America.)[63]

In this crash, the driver's failure to maintain the bus within the travel lane led to the bus's departure from the roadway, initiating a sequence of events that resulted in a complete loss of vehicle control. An LDW system would have notified the driver of an impending lane departure, alerting him to take action to prevent the lane departure (and subsequent crash). Being alerted by an in-vehicle signal to a potential problem, rather than being suddenly faced with the predicament of a roadway departure, might have triggered a less extreme response from the bus driver than his initial steering overcorrection. Had an LDP system been installed on the bus, it would have detected the lane markings on the road's newly paved surface, warned the driver of the movement from the lane, and then, if he did not respond, it would have actively intervened to maintain lane positioning, independent of the reason for the drift from the lane. The NTSB concludes that an LDW system on the bus would have alerted the driver that the bus was departing its travel lane, while an LDP system would have actively assisted the driver to keep the vehicle within the travel lane if he did not react to a warning; either technology might have prevented the series of events that led to the crash.

Lane-keeping system technology has made significant advances in recent years. Today, LDP systems are readily available for commercial vehicles. They often incorporate a warning signal to the driver and provide an enhanced safety effect by automatically returning the vehicle to its travel lane if the driver does not respond to the warning. Had the bus involved in this crash been equipped with an LDP, it would most likely have first alerted the driver that his bus was moving out of the lane and then, if he did not act, would have intervened to keep the bus in its lane, actively preventing the initiation of the crash sequence. An LDW system would have provided a warning but not active intervention.

Despite the significant safety benefits that LDP and LDW systems could have provided to prevent the sequence of events that led to this crash, NHTSA has taken no action and has no plans to address Safety Recommendation H-10-1. Because NHTSA has failed for more than a decade to require that commercial motor vehicles be equipped with LDW systems and, given the advances in lane-keeping system technology, the NTSB classifies Safety Recommendation H-10-1 "Closed—Unacceptable Action/Superseded" and recommends that NHTSA require all newly manufactured commercial motor vehicles with GVWRs above 10,000 pounds to be equipped with LDP systems (Safety Recommendation H-21-1). Because LDP systems are newer and more advanced technologies that differ from the LDW systems called for in Safety

[63] For more information, see Detroit Assurance brochure, accessed March 16, 2021. In late 2019, the Detroit Assurance 5.0 active safety system became standard on Freightliner Cascadia trucks powered by Detroit engines.

Recommendation H-10-1, the NTSB is not issuing this new recommendation with the status of "Open—Unacceptable Response."

2.4 Occupant Protection and Crashworthiness Standards for Medium-Size Buses

When the driver overcorrected his steering, first to the left and then back to the right, the bus rolled left about its longitudinal axis a quarter turn and slid about 85 feet until the roof struck the guardrail end treatment. The bus then rolled another three-quarters of a turn, landing about 43 feet farther east, and coming to final rest on all four wheels, on top of the guardrail.

The forces imposed on the bus's roof as the vehicle rolled compromised the integrity of the roof structure. The roof shifted about 31 inches laterally to the right, exposing the left-side seatbacks through the window openings. The impact of the narrow guardrail end treatment with the bus's roof caused further localized collapse of the roof onto the seatbacks of rows 4–6. When the left side of the roof separated from the left roof rail and left-side windows due to the loss of structural integrity, the risk of passenger ejection increased, especially for unrestrained or loosely restrained occupants.[64] Even properly restrained occupants were at risk of partial ejection and associated injuries because of the exposure of their heads, arms, and upper torsos to the environment outside the vehicle during the overturn sequence.

The following sections discuss how seat belts, roof strength, and window glazing can be integral to protecting occupants during a crash.

2.4.1 Seat Belts

Seat belts are designed to keep passengers in their seats and inside a vehicle. In all, 13 passengers were partially or fully ejected from the bus during the crash sequence and, as a result, sustained serious or fatal injuries. Of these 13 passengers, 6 were belted (some loosely) and sustained serious injuries, 1 was not wearing a seat belt and sustained serious injury, and belt use for the remaining 6 passengers could not be determined (3 fatal and 3 serious injuries).

Postcrash examination of the lap belts did not reveal any evidence of malfunction. The lap belts conformed to federal requirements, and none of the buckles released without depressing the release button. Twenty of the 30 passengers either said that their seat belts were buckled at the time of the crash or sustained abdominal bruising associated with lap belt use.[65] However, some indicated that their seat belts were only loosely worn. To be fully effective, a lap belt must be worn across the pelvic bones and cinched tightly enough to prevent the passenger from slipping out of the seat belt. The NTSB concludes that because some bus passengers did not wear their lap belts and others wore them improperly, the likelihood of these passengers experiencing ejection and/or injury during the rollover crash was increased.

[64] The bus was equipped with Shield Restraint Systems lap belts in all 35 rear passenger seating positions.

[65] The NTSB notes that, during the trip, the tour guide reminded the passengers to use the lap belts.

In a report of an investigation of a 2012 school bus and truck collision near Chesterfield, New Jersey, the NTSB concluded that lap belts can provide a benefit to passengers who wear them properly (NTSB 2013). Properly worn lap belts can reduce occupant motion out of the seating compartment, especially in rollovers. However, the Chesterfield crash investigation also showed that lap-belted occupants are still subject to injuries in a crash as a result of the flailing of their upper bodies. NHTSA has determined that lap/shoulder belt assemblies installed on the passenger seats of over-the-road and other large buses can reduce the risk of fatal injuries in rollover crashes by 77 percent, primarily by preventing occupant ejection. NHTSA found that lap/shoulder belts provide greater restraint of the upper body and distribute the seat belt loading over a larger surface area of the body, reducing the risk of injury.[66] In the Bryce Canyon City rollover crash, lap/shoulder-belted passengers would have had a greater chance of avoiding full and partial ejection, which was the source of numerous serious injuries. The NTSB concludes that, in this crash, properly worn lap/shoulder belts, as opposed to lap-only belts, would have provided a higher level of protection to the bus passengers. This protection is also dependent on roof and window integrity, which is discussed in section 2.4.2 below.

More than 20 years ago, the NTSB published a special investigation report on bus crashworthiness that contained a number of recommendations, including the following two recommendations on occupant protection to NHTSA (NTSB 1999):

H-99-47

> 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-99-48

> 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.

In 2013, NHTSA published a final rule amending FMVSS 208 on occupant protection to require lap/shoulder belts for each passenger seating position on all new over-the-road buses and on new other than over-the-road buses with GVWRs greater than 26,000 pounds (with certain exclusions). Safety Recommendations H-99-47 and -48 were classified "Closed—Acceptable Action."

The 2013 final rule became effective on November 28, 2016; however, the compliance date for multistage buses was 1 year later, November 28, 2017. The bus involved in the crash was built in multiple stages, with the final stage being completed in February 2017; consequently, it was not required to be equipped with passenger lap/shoulder belts (49 *CFR* 571.8[b]). Had this same bus been built today, it would be required to be equipped with passenger lap/shoulder belts.

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[66] See Occupant Crash Protection FMVSSs, accessed March 16, 2021.

The NTSB, however, remains concerned that medium-size buses that do not meet the definition of an over-the-road bus and have GVWRs between 10,000 and 26,000 pounds remain in operation and continue to be manufactured without being required to have lap/shoulder belts at all passenger seating positions. In fact, not even lap belts are required to be installed on such vehicles.

The NTSB has addressed this gap in occupant protection for medium-size buses in other crash investigations. In 2018, as a result of its investigation of a 2017 crash in Concan, Texas, in which a pickup truck crossed the centerline of US Highway 83 and collided with a medium-size bus (NTSB 2018b), the NTSB issued Safety Recommendation H-18-59 to NHTSA, as follows:

H-18-59

> Amend Federal Motor Vehicle Safety Standard 208 to require lap/shoulder belts for each passenger seating position on all new buses with a gross vehicle weight rating of more than 10,000 pounds but not greater than 26,000 pounds.

NHTSA responded to this recommendation on April 18, 2019, stating that it believed amending FMVSS 208 as recommended might not be cost-effective, given seat belt use rates on buses. NHTSA's response to Safety Recommendation H-18-59 also stated that it was continuing to assess the need for medium-size bus occupant protection. NHTSA's reply noted that FMVSS 208 does not prohibit the voluntary installation of passenger seat belts in medium-size buses. On July 1, 2019, the NTSB classified Safety Recommendation H-18-59 "Open—Acceptable Response."

Also in the Concan report, the NTSB made safety recommendations to medium-size bus manufacturers (ARBOC Specialty Vehicles, LLC; Coach & Equipment Manufacturing Corporation; Rev Group, Inc.; Diamond Coach Corporation; Forest River, Inc.; Girardin Blue Bird; SVO Group, Inc.; and Thomas Built Buses) and seat manufacturers (Freedman Seating Company and HSM Transportation Solutions), as follows:

H-18-62 (to bus manufacturers)

> Install lap/shoulder belts in all seating positions as standard, rather than optional, equipment in all newly manufactured medium-size buses.

H-18-63 (to seat manufacturers)

> Supply seating systems equipped with lap/shoulder belts as standard, rather than optional, equipment for medium-size buses.

Of the eight bus manufacturers receiving Safety Recommendation H-18-62, only one, ARBOC Specialty Vehicles, has responded, indicating that it planned to make lap/shoulder belts a standard feature on its buses. The NTSB classified Safety Recommendation H-18-62 "Open—Acceptable Response" for ARBOC Specialty Vehicles on April 5, 2019; the recommendation status is "Open—Await Response" for the other seven recommendation recipients.

Regarding Safety Recommendation H-18-63 to the two seat manufacturers, Freedman Seating Company responded that, although there are currently no requirements for lap/shoulder belts on medium-size buses, the company encourages its customers to purchase such restraint systems. HSM Transportation Solutions has not responded to this recommendation. The NTSB classified Safety Recommendation H-18-63 to Freedman Seating Company "Open—Acceptable Response" on April 24, 2019; the status for HSM Transportation Solutions is "Open—Await Response."

The NTSB has investigated crashes of medium-size buses in which lap/shoulder belts would have mitigated injuries to the passengers, yet these buses were not and are still not required to be equipped with lap/shoulder belts because they do not meet the definition of over-the-road bus or do not exceed 26,000 pounds GVWR.[67] The NTSB considers that relying on voluntary installation of passenger lap/shoulder belts on such buses presents an unacceptable safety risk to their passengers. The NTSB concludes that passengers of all types of medium-size buses should be afforded the same level of occupant protection as passengers on buses with GVWRs over 26,000 pounds, including the availability of lap/shoulder belts at all seating positions. Therefore, the NTSB reiterates Safety Recommendation H-18-59 to NHTSA, as well as Safety Recommendation H-18-62 to bus manufacturers and Safety Recommendation H-18-63 to bus seat manufacturers.

2.4.2 Roof Strength and Window Glazing

The forces on the bus's roof during the rollover caused it to shift to the right; the roof subsequently collapsed onto the seatbacks in rows 4–6 during the collision with the guardrail. Most of the window frames were broken out, and the window glazing on both sides of the bus was compromised during the rollover and subsequent deformation of the roof structure.

The NTSB and NHTSA have found that, in vehicles with large window regions, the glazing materials or the entire window frame can separate from the vehicle during rollovers (NTSB 1999 and 2010, NHTSA 2006). In a high-speed rollover, if the roof structure shifts, window frames can distort, allowing the glazing to become displaced and fractured, resulting in occupants being at risk of full or partial ejection through the openings. In this crash, the loss of window glazing, in combination with improper or no seat belt use, contributed to 11 occupant ejections and 2 partial ejections. With the shifting of the bus roof, the head and extremities of even a properly restrained passenger could have been exposed to the outside environment during the rollover.

The NTSB addressed window glazing and roof strength in its bus crashworthiness special investigation report, resulting in the issuance of Safety Recommendations H-99-49, -50, and -51 (NTSB 1999), as well as in the Dolan Springs crash report (NTSB 2010), resulting in the issuance of Safety Recommendation H-10-3. These four recommendations to NHTSA read as follows:

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[67] See the NTSB's Concan, Texas, (NTSB 2018b) and Dolan Springs, Arizona, (NTSB 2010) crash reports.

<u>H-99-49</u>

> Expand your research on current advanced glazing to include its applicability to motorcoach occupant ejection prevention, and revise window glazing requirements for newly manufactured motorcoaches based on the results of this research.

<u>H-99-50</u>

> 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.

<u>H-99-51</u>

> Once performance standards have been developed for motorcoach roof strength, require newly manufactured motorcoaches to meet those standards.

<u>H-10-3</u>

> In your rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a gross vehicle weight rating above 10,000 pounds, other than school buses.

All four of these safety recommendations are currently classified "Open—Unacceptable Response."

Since these recommendations were issued, the NTSB has reiterated them in multiple crash reports. Safety Recommendation H-99-49 was reiterated in three separate crash reports involving motorcoach roadway departures—the 2001 New Orleans, Louisiana, report; the 2012 Doswell, Virginia, report; and the 2018 Laredo, Texas, report (NTSB 2001, 2012, and 2018c). Safety Recommendations H-99-50 and -51 were reiterated in three separate crash reports involving motorcoach roadway departures—the 2001 New Orleans, Louisiana, report; the 2009 Sherman, Texas, report; and the 2012 Doswell, Virginia, report (NTSB 2001, 2009, and 2012). In 2014, the NTSB began investigating a crash involving the median crossover of a truck-tractor semitrailer and its collision with a medium-size bus in Davis, Oklahoma. In its report on the Davis crash, which highlighted the need for bus structural integrity and advanced window glazing to reduce the risk of occupant ejection during a rollover (NTSB 2015b), the NTSB reiterated Safety Recommendation H-10-3 to NHTSA.

In response to these safety recommendations and the requirements of MAP-21, NHTSA published an NPRM in 2014 on enhancing the rollover structural integrity of all new over-the-road buses and new other than over-the-road buses with GVWRs greater than 26,000 pounds.[68] NHTSA also published an NPRM in May 2016 addressing the installation of advanced window glazing in all new over-the-road buses and new other than over-the-road buses with GVWRs greater than

[68] (a) *Federal Motor Vehicle Safety Standards*, "Bus Rollover Structural Integrity, Motorcoach Safety Plan," proposed rule, August 6, 2014 (79 *Federal Register* 46090, docket no. NHTSA-2014-0085). (b) As noted earlier in this report, MAP-21 refers to the Moving Ahead for Progress in the 21st Century Act (P.L. 112–141), which mandated motorcoach rulemakings and research projects on crashworthiness and crash avoidance. (For more information, see Public Law 112–141, accessed March 16, 2021.)

26,000 pounds.[69] The NTSB supported these NHTSA efforts (as well as urging NHTSA to include all medium-size buses with GWVRs of 26,000 pounds and under in the rulemaking).[70] However, to date, no further action has occurred on these NPRMs. Based on the bus definitions in each NPRM, both proposed rules would have applied to over-the-road buses such as the one involved in this crash.

The NTSB is disappointed that NHTSA has not proceeded further with rulemaking to improve roof structural integrity and window glazing for all buses. Given that the roof of the bus in this crash shifted and collapsed during the crash sequence and that the window frames were displaced and the window glazing failed, creating greater risk for occupant ejection, rulemaking to require improved structural integrity and advanced window glazing is still needed to protect bus occupants. The NTSB concludes that, as demonstrated by this medium-size bus crash, structural improvements to enhance roof strength and advanced window glazing are needed to help maintain survival space and reduce the risk of ejection for bus occupants.

Safety Recommendation H-10-3 addresses occupant protection (particularly seat belts), roof strength, and window glazing in buses with GVWRs greater than 10,000 pounds. After Safety Recommendation H-10-3 was issued, NHTSA made progress in the area of occupant protection when it amended FMVSS 208 to require lap/shoulder belts for each passenger seating position in all new over-the-road buses and in new buses other than over-the-road buses with GVWRs greater than 26,000 pounds, a subset of the buses identified in Safety Recommendation H-10-3. The NTSB notes that Safety Recommendation H-18-59 recommends that NHTSA amend FMVSS 208 to require lap/shoulder belts for each passenger seating position on all new buses with GVWRs between 10,000 and 26,000 pounds and addresses the remaining group of medium-size buses for which there are no restraint requirements.

NHTSA, however, has not finalized rulemaking action for roof strength or window glazing for any size bus.[71] More than 20 years have passed since the NTSB issued Safety Recommendations H-99-49 through -51 to NHTSA and more than 10 years have passed since the NTSB issued Safety Recommendation H-10-3 to NHTSA. During this period, the NTSB has investigated other crashes that have shown the continuing need for the recommended actions, yet NHTSA has not addressed the safety issues in these recommendations. The NTSB concludes that, because NHTSA has failed to establish roof strength and window glazing standards for buses with GVWRs above 10,000 pounds, the occupants of these buses have been inadequately protected during crashes, particularly rollover crashes. Consequently, the NTSB classifies Safety Recommendations H-99-50 and -51 and H-10-3 “Closed—Unacceptable Action/Superseded.” The NTSB supersedes these recommendations with the following new recommendation:

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[69] *Federal Motor Vehicle Safety Standards*, “Bus Emergency Exits and Window Retention and Release, Anti-Ejection Glazing for Bus Portals,” proposed rule, May 6, 2016 (81 *Federal Register* 27904, docket no. NHTSA-2016-0052).

[70] To view the NTSB comments on these rulemaking actions in full, see NTSB 2014 comments on the structural integrity rule and NTSB 2016 comments on the glazing rule, both accessed March 16, 2021.

[71] As provided in FMVSS 222, school buses must meet certain roof strength requirements.

<u>H-21-2</u>

> Require all newly manufactured buses, other than school buses, with GVWRs above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions.

Further, the NTSB classifies Safety Recommendations H-99-49 and H-10-3 "Closed—Unacceptable Action/Superseded." The NTSB supersedes these recommendations with the following new safety recommendation:

<u>H-21-3</u>

> Require all newly manufactured buses, other than school buses, with GVWRs above 10,000 pounds to meet a window glazing standard that prevents occupant ejection.

Because the new Safety Recommendations H-21-2 and -3 reflect the same concerns regarding roof strength and window glazing (respectively) that NHTSA has failed to resolve in the years since Safety Recommendations H-99-49 through -51 and H-10-3 were first issued, the NTSB also classifies new Safety Recommendations H-21-2 and -3 "Open—Unacceptable Response."

3 Conclusions

3.1 Findings

1. None of the following were factors in this crash: (1) mechanical operation of the bus; (2) design, markings, signage, or friction characteristics of the highway; (3) motor carrier operations or state or federal oversight of the motor carrier; (4) driver experience, licensing, alcohol or drug use, fatigue, distraction, or medical issues; and (5) weather or illumination.

2. The emergency response and the transportation of the injured passengers were timely and adequate.

3. The bus driver failed to keep the bus within the travel lane for undetermined reasons, and the bus's right-side tires left the roadway.

4. The driver responded to the bus's departure from the roadway first by overcorrecting to the left to reenter the roadway, and then by overcorrecting to the right, after the bus had begun to enter the opposing travel lane; these overcorrections caused the bus to become unstable and to roll over.

5. Had the bus been equipped with an electronic stability control system, the technology would have assisted the driver in maintaining control of the bus and reduced the likelihood of vehicle rollover.

6. The safety of buses with gross vehicle weight ratings between 10,000 and 26,000 pounds would be enhanced by equipping them with electronic stability control systems.

7. The lane markings on State Route 12 were visible and in good condition; therefore, a lane departure warning or prevention system should have been able to detect and recognize the lane markings and provide appropriate alerts or action in response to the bus's departure from the lane.

8. A lane departure warning system on the bus would have alerted the driver that the bus was departing its travel lane, while a lane departure prevention system would have actively assisted the driver to keep the vehicle within the travel lane if he did not react to a warning; either technology might have prevented the series of events that led to the crash.

9. Because some bus passengers did not wear their lap belts and others wore them improperly, the likelihood of these passengers experiencing ejection and/or injury during the rollover crash was increased.

10. In this crash, properly worn lap/shoulder belts, as opposed to lap-only belts, would have provided a higher level of protection to the bus passengers.

11. Passengers of all types of medium-size buses should be afforded the same level of occupant protection as passengers on buses with gross vehicle weight ratings over 26,000 pounds, including the availability of lap/shoulder belts at all seating positions.

12. As demonstrated by this medium-size bus crash, structural improvements to enhance roof strength and advanced window glazing are needed to help maintain survival space and reduce the risk of ejection for bus occupants.

13. Because the National Highway Traffic Safety Administration has failed to establish roof strength and window glazing standards for buses with gross vehicle weight ratings above 10,000 pounds, the occupants of these buses have been inadequately protected during crashes, particularly rollover crashes.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Bryce Canyon City, Utah, crash was the bus driver's failure, for undetermined reasons, to maintain the bus within its travel lane and his subsequent steering overcorrections, which caused the bus to become unstable and roll over. Contributing to the severity of the crash was the roof's deformation, caused by the rollover, and its further collapse upon impact with the guardrail, which created ejection portals and compromised the survival space of the passenger seating compartment. Also contributing to the severity of the crash was the National Highway Traffic Safety Administration's failure to develop and promulgate standards for bus roof strength and window glazing to enhance the protection of bus passengers. Contributing to the ejections and the severity of the injuries was the lack of passenger lap/shoulder belts on the bus.

4 Recommendations

4.1 New Recommendations

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

To the National Highway Traffic Safety Administration:

> Require all newly manufactured commercial motor vehicles with gross vehicle weight ratings above 10,000 pounds to be equipped with lane departure prevention systems. (H-21-1) *[This new recommendation supersedes Safety Recommendation H-10-1.]*
>
> Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions. (H-21-2) *[This new recommendation supersedes Safety Recommendations H-99-50 and -51 and H-10-3, and it is initiated with the status "Open—Unacceptable Response."]*
>
> Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a window glazing standard that prevents occupant ejection. (H-21-3) *[This new recommendation supersedes Safety Recommendations H-99-49 and H-10-3, and it is initiated with the status "Open—Unacceptable Response."]*

4.2 Previously Issued Recommendations Reiterated in This Report

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

To the National Highway Traffic Safety Administration:

> Develop stability control system performance standards for all commercial motor vehicles and buses with a gross vehicle weight rating greater than 10,000 pounds, regardless of whether the vehicles are equipped with a hydraulic or a pneumatic brake system. (H-11-7)
>
> Once the performance standards from Safety Recommendation H-11-7 have been developed, require the installation of stability control systems on all newly manufactured commercial vehicles with a gross vehicle weight rating greater than 10,000 pounds. (H-11-8)
>
> Safety Recommendations H-11-7 and -8 are reiterated in section 2.3.1 of the report.

> Amend Federal Motor Vehicle Safety Standard 208 to require lap/shoulder belts for each passenger seating position on all new buses with a gross vehicle weight rating of more than 10,000 pounds but not greater than 26,000 pounds. (H-18-59)
>
> Safety Recommendation H-18-59 is reiterated in section 2.4.1 of the report.

To the bus manufacturers ARBOC Specialty Vehicles, LLC; Coach & Equipment Manufacturing Corporation; Rev Group, Inc.; Diamond Coach Corporation; Forest River, Inc.; Girardin Blue Bird; SVO Group, Inc.; and Thomas Built Buses:

> Install lap/shoulder belts in all seating positions as standard, rather than optional, equipment in all newly manufactured medium-size buses. (H-18-62)
>
> Safety Recommendation H-18-62 is reiterated in section 2.4.1 of the report.

To the bus seat manufacturers Freedman Seating Company and HSM Transportation Solutions:

> Supply seating systems equipped with lap/shoulder belts as standard, rather than optional, equipment for medium-size buses. (H-18-63)
>
> Safety Recommendation H-18-63 is reiterated in section 2.4.1 of the report.

4.3 Previously Issued Recommendations Classified in This Report

To the National Highway Traffic Safety Administration:

> Expand your research on current advanced glazing to include its applicability to motorcoach occupant ejection prevention, and revise window glazing requirements for newly manufactured motorcoaches based on the results of this research. (H-99-49)

The classification of Safety Recommendation H-99-49 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-3 in section 2.4.2 of this report.

> 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)

The classification of Safety Recommendation H-99-50 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-2 in section 2.4.2 of this report.

> Once performance standards have been developed for motorcoach roof strength, require newly manufactured motorcoaches to meet those standards. (H-99-51)

The classification of Safety Recommendation H-99-51 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-2 in section 2.4.2 of this report.

> Require new commercial motor vehicles with a gross vehicle weight rating above 10,000 pounds to be equipped with lane departure warning systems. (H-10-1)

The classification of Safety Recommendation H-10-1 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendation H-21-1 in section 2.3.2 of this report.

> In your rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a gross vehicle weight rating above 10,000 pounds, other than school buses. (H-10-3)

The classification of Safety Recommendation H-10-3 is changed from "Open—Unacceptable Response" to "Closed—Unacceptable Action/Superseded" by new Safety Recommendations H-21-2 and -3 in section 2.4.2 of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Report Date: May 10, 2021

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of the Bryce Canyon City, Utah, crash on September 20, 2019, and dispatched an investigative team to the site. The NTSB established groups to investigate human performance; motor carrier operations; and highway, survival, and vehicle factors.

Parties to the investigation were the Federal Motor Carrier Safety Administration, Utah Highway Patrol, Utah Department of Transportation, California Highway Patrol, and Daimler Trucks North America.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* (USC) 11179(b) requires the following information on the recommendations in this report.

For each recommendation—

(1) a brief summary of the NTSB's collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the NTSB's use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation to the extent such actions are known to the Board, that were consistent with the recommendation.

To the National Highway Traffic Safety Administration:

H-21-1

Require all newly manufactured commercial motor vehicles with gross vehicle weight ratings above 10,000 pounds to be equipped with lane departure prevention systems.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.3.2 Lane Departure Prevention and Warning Systems. Information supporting (b)(1) can be found on pages 30–32; (b)(2) and (b)(3) are not applicable.

H-21-2

Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions.

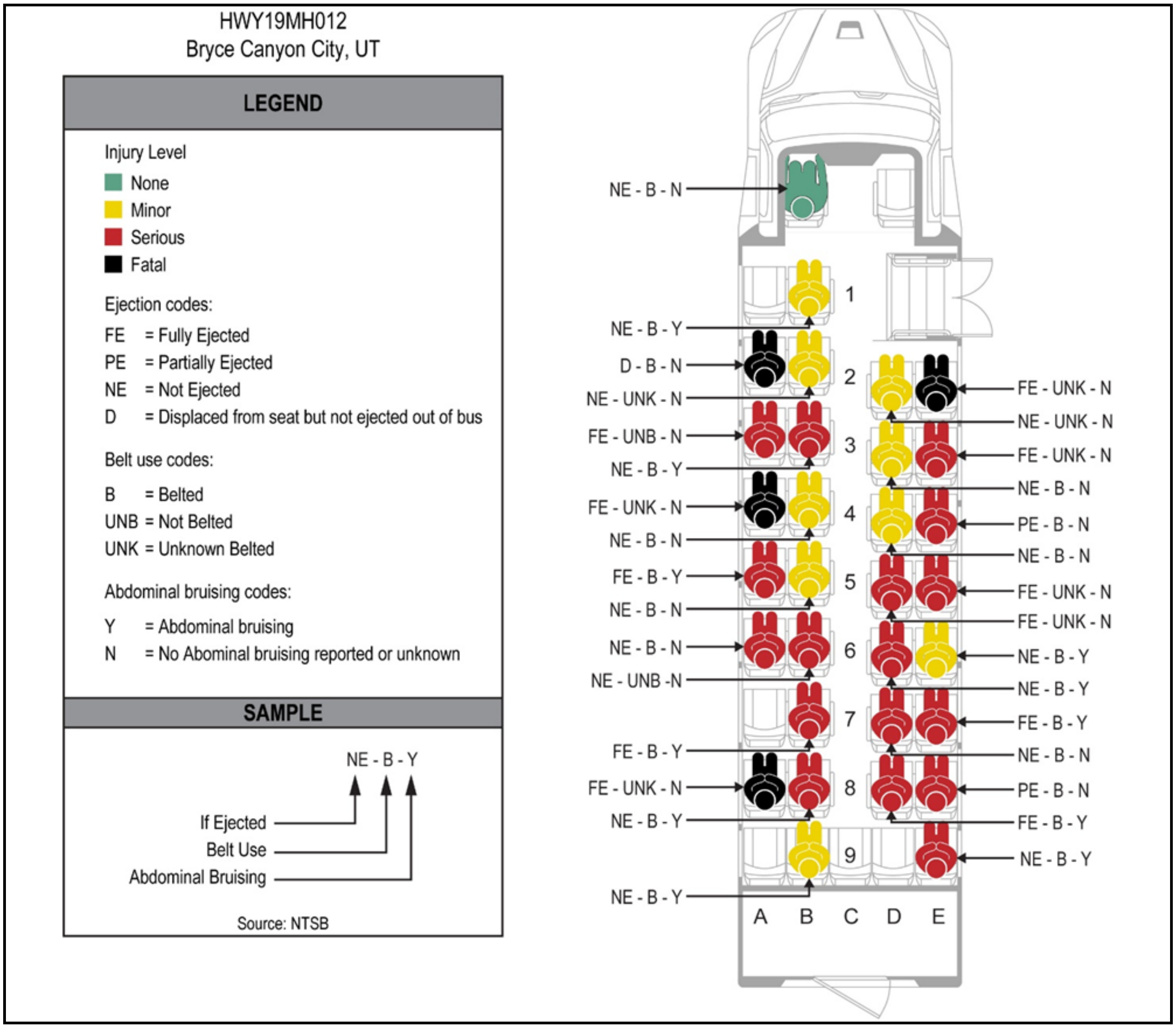
Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.4.2 Roof Strength and Window Glazing. Information supporting (b)(1) can be found on pages 36–39; (b)(2) and (b)(3) are not applicable.

H-21-3

> Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a window glazing standard that prevents occupant ejection.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.4.2 Roof Strength and Window Glazing. Information supporting (b)(1) can be found on pages 36–39; (b)(2) and (b)(3) are not applicable.

Appendix C: Seating Chart with Injury, Ejection, and Seat Belt Use Information



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