October 18, 2022 NTSB/HIR-22/06

Collision Between Service Vehicle and School Bus

Decatur, Tennessee

October 27, 2020

Abstract: On Tuesday, October 27, 2020, about 3:45 p.m. eastern daylight time, a utility service truck was northbound on the two-lane State Route 58 (SR-58) in Decatur, Meigs County, Tennessee. At the same time, a transit-style school bus was traveling south, carrying 33 students home from school. The truck driver reported that he was looking in his side rear-vision mirrors when the truck's right-side wheels departed the roadway and entered the earthen v-ditch adjacent to the paved rumble-milled shoulder. When the truck driver steered the truck back onto the roadway, the truck yawed counterclockwise and crossed into the southbound lane. The bus collided with the right side of the truck, fatally injuring the 53-year-old bus driver and a 7-year-old passenger seated directly behind the bus driver. Four other school bus passengers sustained serious injuries, 10 sustained minor injuries, and 18 were uninjured or their injury level was unknown. The truck driver was also uninjured. The safety issues addressed in this report include inadequate roadway design of State Route 58, lack of lane departure warning and prevention systems for heavy vehicles, and lack of sufficient passenger protection measures on school buses.

NOTE: This report was reissued November 16, 2022, with a corrected NTIS number on page 57.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
CDL	commercial driver's license
CDLIS	Commercial Driver's License Information System
CFR	*Code of Federal Regulations*
CPAP	continuous positive airway pressure
DOT	US Department of Transportation
ECM	engine control module
EMS	emergency medical services
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
FMVSS	Federal Motor Vehicle Safety Standard
GPS	global positioning system
GVWR	gross vehicle weight rating
LDP	lane departure prevention
LDW	lane departure warning
LKA	lane-keeping assist
MCSD	Meigs County Sheriff Department
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
OSA	obstructive sleep apnea
SEC	Service Electric Company
SR-58	State Route 58

TDOT	Tennessee Department of Transportation
THP	Tennessee Highway Patrol

Executive Summary

What Happened

On Tuesday, October 27, 2020, about 3:45 p.m. eastern daylight time, a 2018 Freightliner truck, configured as a service vehicle for a local utility company, was traveling north on State Route 58 (SR-58) in Decatur, Meigs County, Tennessee, at an estimated speed of about 52 mph. At the same time, a 2013 Thomas Built transit-style school bus was traveling southbound on SR-58, carrying 33 students home from school. The bus was traveling at a recorded speed of 46 mph immediately prior to impact. The posted speed limit was 55 mph.

In the area of the crash, the highway has one lane in each direction separated by a double yellow centerline. Adjacent to the northbound travel lane is a paved shoulder about 1 foot wide with milled rumble stripes. Next to the northbound paved shoulder was an earthen v-ditch.

The truck driver reported that he was looking in his side rear-vision mirrors when the truck's right-side wheels departed the roadway and entered the v-ditch. When the truck driver steered the truck back onto the roadway, the truck yawed counterclockwise, crossed into the southbound lane and was almost perpendicular to the roadway. The bus collided with the right side of the truck.

The 53-year-old school bus driver and a 7-year-old passenger seated directly behind the bus driver were fatally injured. Four other school bus passengers sustained serious injuries, 10 sustained minor injuries, and 18 were uninjured or their injury level was unknown. The truck driver was also uninjured.

What We Found

We found that lane departure warning systems and lane-keeping assist systems can prevent many lane and road departure crashes, and may have averted this crash. Also, the truck driver's ability to return to the roadway was affected negatively by the non-recoverable and critical foreslopes of the earthen v-ditch (design aspects of the slope away from the roadway from which drivers may be unable to recover their vehicles) and the drop-off edge of the paved shoulder. Since the crash, the Tennessee Department of Transportation has made improvements to SR-58 in the area of the collision that address these deficiencies.

We also found that several of the school bus passengers were not seated properly in their seats, which increased their risk of injury. Lap/shoulder belts would have mitigated the forward inertial movement of the unbelted passengers on the school bus, keeping them within the protecting seating compartment and reducing their risk of injury. Onboard video recorder information can be used to identify risky student behaviors such as out-of-position seating positions to proactively correct these positions and maximize occupant protection for compartmentalized passengers.

We determined that the probable cause of the Decatur, Tennessee, crash was the service truck driver's inattention to the forward roadway due to his looking at a sheriff's vehicle behind him, which resulted in his failure to keep the truck on the roadway. Contributing to the cause of the crash were non-recoverable and critical foreslopes and the pavement edge drop-off along the state highway, which prevented the truck driver from safely returning the truck to the roadway in a controlled manner. Contributing to the severity of the crash was the lack of passenger lap/shoulder belts on the school bus and the unsafe seating positions by some of the students.

What We Recommended

As a result of this investigation, we issued one new recommendation and we reiterated four recommendations. We issued a recommendation to the National Association for Pupil Transportation, the National Association of State Directors of Pupil Transportation Services, and the National School Transportation Association to inform their members to periodically review onboard video event recorder information to ensure that students engage in safe transportation behaviors on school buses, including sitting properly and wearing seat belts, when available, and that the members use this information to improve the bus safety training provided to drivers, students, and parents.

We reiterated Safety Recommendations H-21-1 and H-22-3 to the National Highway Traffic Safety Administration (NHTSA) to require lane departure prevention systems on new vehicles with gross vehicle weight ratings greater than 10,000 pounds, and to require all buses and trucks over 10,000 pounds gross vehicle weight rating to be equipped with onboard video event recorders. We reiterated Safety Recommendation H-18-9 to Florida, Louisiana, and New York to amend their statutes to require lap/shoulder belts for all passenger seating positions in new large school buses. We also reiterated Safety Recommendation H-18-10 to the states, commonwealths, and the District of Columbia that do not currently require lap/shoulder belts on new school buses to enact legislation that requires new large school buses to be equipped with passenger lap/shoulder belts.

1. Factual Information

1.1 Crash Narrative

On Tuesday, October 27, 2020, about 3:45 p.m. eastern daylight time, a 2018 Freightliner truck, configured as a service vehicle for a local utility company, was traveling north on State Route 58 (SR-58) at an estimated speed of about 52 mph in Decatur, Meigs County, Tennessee, when it departed the roadway to the right, returned to the roadway, and crossed over into the opposite travel lane.[1] At the same time, a 2013 Thomas Built transit-style school bus was traveling southbound on SR-58 at a recorded speed of 46–48 mph, carrying 33 students home from school.[2] The bus collided with the right side of the service truck. In that area, the highway has one lane in each direction separated by a double yellow centerline (see figure 1) and a posted speed limit of 55 mph. Adjacent to the northbound travel lane is a paved shoulder about 1 foot wide with milled rumble stripes.[3] Next to the northbound paved shoulder was an earthen v-ditch.[4] The weather was clear and the roadway was dry.

[1] (1) All times are presented in eastern daylight time. (2) Visit ntsb.gov to find additional information in the public docket for this NTSB investigation (case number HWY21FH001). Use the CAROL Query to search safety recommendations and investigations.

[2] The school bus was equipped with an outward-facing camera that captured video footage of the truck's precrash movement. The video footage was analyzed to estimate the speed of the truck. The global positioning system (GPS)-based speed of the bus was displayed on the video footage. The school bus was also equipped with inward-facing cameras that captured video footage of the passengers. See section 1.9.1 for additional information on the video study.

[3] A *rumble stripe* is a rumble strip with the edgeline marked over the rumble strip and is usually applied on state highways with narrow shoulders. For more detail, including photos and diagrams, see section 1.5 Highway Information.

[4] A *v-ditch* is an earthen channel that collects drainage from a roadway before reaching an adjacent property. The v-ditch contains a foreslope (the portion of the v-ditch that slopes down and away from the roadway toward the bottom of the v-ditch) and backslope (the portion of the v-ditch that slopes upward and away from the bottom of the v-ditch to the top of the existing terrain). For more detail, including photos and diagrams, see section 1.5 Highway Information.

Figure 1. Northbound view of SR-58. (Source: Tennessee Department of Transportation)

The impact occurred in the 7700 block of SR-58 about 66 feet from the south end of a 287-foot-long, 900-foot radius curve in the southbound lane (see figure 2).

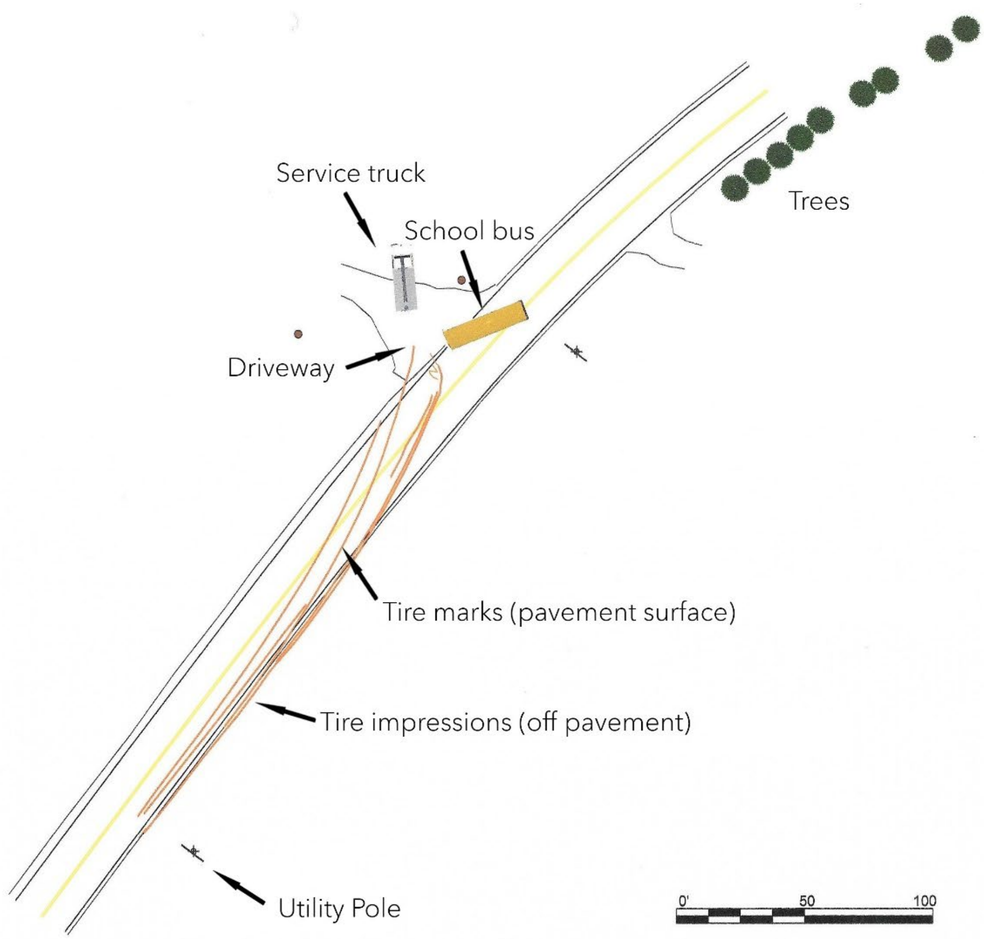

Figure 2. Diagram depicting vehicles' postcrash positions of rest, with tire mark/impression evidence. (Source: Tennessee Highway Patrol. Trees and utility poles added by NTSB, based on Google Earth imagery.)

About 206 feet before the area of impact, the truck's right-side wheels departed the pavement at an estimated departure angle of 1.5° (see figure 3, picture A). The truck driver told investigators that he was looking behind the truck in his side rear-vision mirrors at a sheriff deputy's vehicle that had turned onto SR-58 heading north behind the truck.[5] Tire impressions in the soil, tire markings on the pavement, and video evidence from the outward-facing camera on the school bus

[5] Title 49 *Code of Federal Regulations* (*CFR*) 393.80 requires trucks to have *rear-vision mirrors* (commonly referred to as *rear-view mirrors*) attached at the sides of the truck on the outside.

showed that only the right-side wheels departed the pavement area.[6] After 139 feet (about 67 feet before the impact area), tire impressions and video footage indicated movement of the steer (front) axle wheels to the left as the truck's right front wheel began to return to the roadway (see figure 3, picture B). Additionally, the video footage showed soil being displaced by the right rear tires and a loss of traction. Video from the school bus's outward-facing camera showed that the truck had substantially yawed and the left front wheel was across the highway centerline (see figure 3, picture C). About a second after the truck's right front wheel re-entered the roadway, the truck crossed the highway centerline into the southbound lane and yawed nearly 90° to be almost perpendicular to the roadway just before impact with the bus (see figure 3, picture D).

Figure 3. Video frames, captured by the outward-facing camera onboard the school bus, showing the truck departing the road (A), returning to the road (B), and crossing into the travel lane of the bus (C & D). The inserts are close-up images of the truck.

The southbound bus would have traveled about 221 feet through the curve before it collided with the right side of the truck aft of the cab. After passing the trees and utility pole along the east side of the highway, the school bus driver would have had an unobstructed view of the truck for about 4–5 seconds before impact. The school bus video indicated that the bus driver had just slightly more than 2 seconds

[6] Tennessee Department of Transportation (TDOT) survey data and Tennessee Highway Patrol mapping data documented the presence of roadway surface tire friction marks and tire impressions in the soil adjacent to the northbound pavement edge.

(an estimated 2.2 seconds) to detect movement of the truck back onto the roadway and toward the southbound lane, interpret it as a hazard, and initiate braking to stop the bus. Inward-facing video of the bus passengers shows forward movement of all the passengers simultaneously, indicating vehicle deceleration about 1–2 seconds before impact.

Postimpact, the bus was redirected northward about 10–12 feet and rotated clockwise about 22°, coming to rest in the southbound lane. At final rest, the truck had rotated about 35° clockwise from its impact with the bus and entered a driveway on the west side of the roadway. Figure 4 shows the final rest positions of the two vehicles.

Figure 4. Final rest positions of truck and school bus. (Source: Tennessee Highway Patrol)

1.2 Injuries and Restraint Use

Injury information for the 35 people involved in this crash is shown in table 1.[7] The truck driver was restrained by a lap/shoulder belt and was not injured in the crash. The school bus driver, who was restrained with a lap/shoulder belt, and one school bus passenger sustained fatal injuries. In addition, 4 school bus passengers sustained serious injuries, 10 sustained minor injuries, and 18 were not injured or their injury level was unknown.[8] The school bus was not equipped with passenger lap or lap/shoulder belts.

Table 1. Classification of injuries.

Occupant	Fatal	Serious	Minor	None	Unknown	Total
Truck driver	0	0	0	1	0	1
School bus driver	1	0	0	0	0	1
School bus passengers	1	4	10	13	5	33
Total	2	4	10	14	5	35

NOTE: Although Title 49 *Code of Federal Regulations* (*CFR*) Part 830 pertains only to the reporting of aircraft accidents and incidents to the National Transportation Safety Board (NTSB), section 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% of the body surface.

Figure 5 shows the school bus passengers' seating position, age, sex, and injury level. The footage captured by the inward-facing cameras on the school bus was used to determine where the passengers were seated (location on the bus) and

[7] The injury classifications are taken from the THP police report. Medical records and autopsy reports were obtained for the seriously and fatally injured occupants. Medical records were not collected for the occupants classified with minor injuries. Complete medical information may not be reflected in the police report.

[8] The injury level for five of the students was unknown, but they were not transported to the hospital from the scene and did not report being treated for crash-related injuries at a later time.

how they were seated (that is, forward-facing with feet on the floor or out of position).[9]

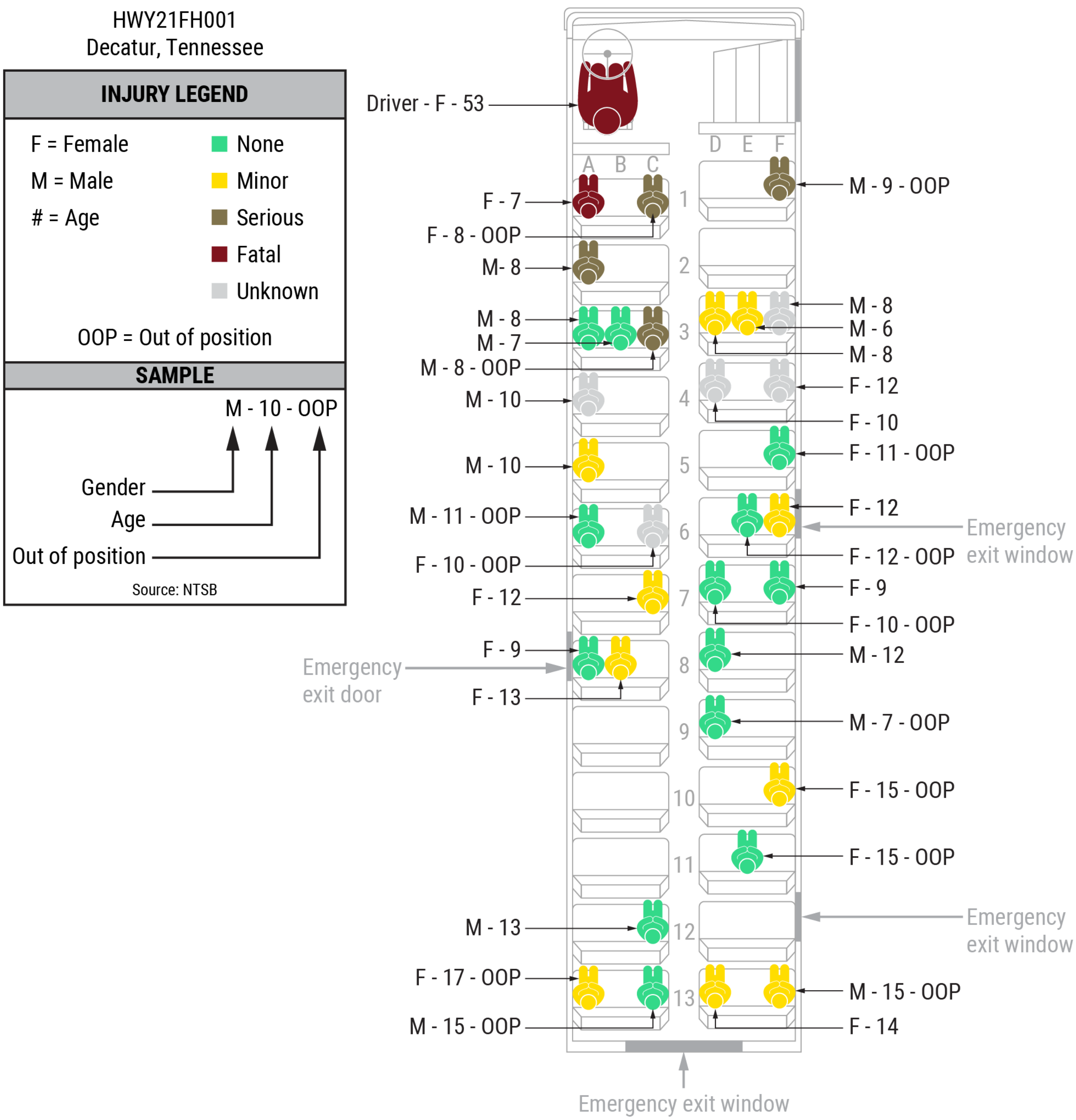

Figure 5. Bus diagram showing occupant seating position, sex, age, and injury level.

[9] The NTSB identified several school bus passengers who were out of position in their seats. That is, they were not seated forward-facing in the bus seat. Instead, they were kneeling on the seat, facing backwards, and/or turned toward the aisle.

The school bus passengers who sustained fatal and serious injuries were seated in the first three rows of the passenger seating compartment. The fatally injured passenger (1A) was seated behind the driver in the window seat in the first row with her head and left shoulder resting on the sidewall of the bus below the window frame. The seriously injured passenger seated in the first row on the left near the aisle (1C) was kneeling on the seat and facing aft. The passenger seated in the first row on the right side of the bus (1F) could be seen in the video facing aft, and was either standing or kneeling on the seat, with his upper body above the partition separating the stairwell from the seating compartment. He sustained serious injuries. The passenger seated in the second row on the left side of the bus (2A), who sustained serious injuries, was not visible in the video, as his head was below the level of the seatback. The seriously injured passenger in the aisle seat of the third row on the left side (3C) was facing aft, partially in the aisle, and was either seated or standing. The video showed that the other students in row 3 appeared to be seated and facing forward just before the crash and suffered minor injuries, no injuries, or their injury level was unknown.

The passengers in rows 4 through 13 suffered minor injuries, no injury, or their injury level was unknown (but they were not transported to the hospital). Video footage showed that 11 of the passengers in these rows (5F, 6A, 6C, 6E, 7D, 9D, 10F, 11E, 13A, 13C, and 13F) were not seated forward-facing in their seats. For example, they were seated sideways with their legs in the aisle or with their knees up on the seatback and feet off the floor.

1.3 Emergency Response

In addition to the Meigs County sheriff's deputy driving behind the truck, two vehicles were following behind the bus: a passenger vehicle and another Meigs County sheriff's deputy vehicle. All drivers witnessed the crash and provided immediate assistance. The Tennessee Highway Patrol (THP) was notified of the crash at 3:45 p.m.[10] The Meigs County Sheriff Department (MCSD) was notified of the crash at 3:48 p.m.; additional MCSD personnel were dispatched at 3:50 p.m. and arrived on scene at 3:55 p.m. The Decatur City Police Department was dispatched at 3:51 p.m., and personnel were on scene at 3:55 p.m. THP personnel arrived at 4:05 p.m. The Meigs County Fire and Rescue and the Decatur City Fire Department also responded, and personnel arrived on scene at 3:57 p.m. and 4:13 p.m., respectively.

Ground and air emergency medical services (EMS) units were dispatched by 3:53 p.m. The first helicopter arrived on scene at 4:28 p.m. Injured bus passengers

[10] The THP event chronology was converted from central daylight time to eastern daylight time for consistency with the time zone in Meigs County.

who were transported by either air or ground EMS departed the scene by 4:50 p.m. and most were transported to Erlanger Baroness Hospital (about 36 miles away). The four seriously injured passengers were transported by air EMS and all arrived by 5:24 p.m. According to the MCSD report, at 4:03 p.m. transportation arrangements for the uninjured school bus passengers were initiated, and they were enroute from the scene at 4:09 p.m. by bus to Meigs South Elementary School. The THP reopened the road at 11:29 p.m. that evening.

1.4 Vehicle Information

1.4.1 Service Truck

General Information. The truck was a 2018 Freightliner M2106 chassis with an Iowa Mold Tooling Co. body and was equipped with a telescopic crane arm. The completed vehicle's gross vehicle weight rating (GVWR) was 33,000 pounds.[11] The truck was not equipped with available collision mitigation technology, such as lane departure or forward collision warning systems.

Maintenance records for the truck showed that Service Electric Company (SEC) conducted preventive and scheduled maintenance that met or exceeded Federal Motor Carrier Safety Regulation (FMCSR) requirements.[12] The truck passed an annual inspection on May 14, 2020, in compliance with federal requirements. At the time of the crash, no recalls had been reported for this vehicle in the National Highway Traffic Safety Administration's (NHTSA) recall database.

Damage. The damage to the truck was concentrated to the right side aft of the passenger compartment, as shown in figure 6.[13] Both right-side cargo doors of the truck's utility box were heavily damaged in the collision, and the forward cargo door separated from the truck. The left photo in figure 6 shows the damaged truck at the crash site without the cargo door; in the right photo at the garage, the damaged door is shown propped up in its original/intended position. The truck sustained a large hole below the forward cargo door latch assembly, and two circular imprints from the bus's right-side headlight assembly were located forward of the large hole on the cargo door. The wheel mounted on the right outside position of the second axle also

[11] *Gross vehicle weight rating* (GVWR) is the total maximum weight that a vehicle is designed to carry when loaded, including the weight of the vehicle itself plus fuel, passengers, and cargo.

[12] FMCSRs set forth minimum safety standards for motor carriers and drivers. For more detail, see 49 CFR Chapter III Subchapter B -- Federal Motor Carrier Safety Regulations (accessed August 10, 2022). See 49 *CFR* Part 392 (driving of commercial vehicles), 393 (parts and accessories necessary for safe operation), and 396 (inspection, repair, and maintenance) for more detail.

[13] *Left* refers to the driver side and *right* refers to the passenger-loading or curb side of the vehicle.

sustained crash damage. The rear cab supports and mounts were torn away from the bottom of the cab, and the right rear corner of the cab was dented.

Figure 6. Postcrash photos of right side of the service truck. (Source: THP)

Figure 7 shows the abrasions and transfer marks on the right side of the crane arm located above and aft of the cargo doors. The crane arm had imprints from the bus's left-side amber and red crossover lights as well as imprints from the bus's center identification lights (circled in figure 7) and from the "school bus" sign, located above the bus's windshield.

Figure 7. Damaged crane arm of service truck.

The right side of the front grill as well as the headlight and trim were broken. The rear and left side of the utility box did not sustain any crash-related damage.

Investigators found no preexisting defects or crash damage to the hydraulic power-assisted steering system, the suspension system, or the dual air-operated antilock brake system. Tire tread depths on the truck's two tires on the steer (front) axle and four tires on the drive (rear) axle were within regulations for commercial trucks and no precrash defects were found on the tires.[14]

Vehicle-Recorded Data. The truck was equipped with a Cummins B6.7 engine controlled by an engine control module (ECM).[15] The data report generated from the ECM showed 22 deceleration occurrences since the truck had been in operation, but none of the decelerations could be attributed to this crash.[16] According to the manufacturer, a complete shutdown sequence requiring the driver to set the parking brake and turn the engine off with a key is necessary to store the recorded events that occur between the power-up and shutdown of the vehicle. This truck sustained an instantaneous shutdown of the electrical system in the collision.

1.4.2 School Bus

General. The 2013 Thomas Built school bus was a transit-style (flat front or Type D), diesel-powered bus. It was equipped with a Cummins ISB6.7 engine located in the rear, hydraulic power steering, automatic transmission, and antilock brakes. The GVWR was 33,000 pounds. Maintenance records provided by Meigs County School District showed that scheduled maintenance and as-needed repairs had been made to the bus. The brakes were replaced in September 2020, and new tires were placed on axle 1 in September 2020 and on axle 2 in March 2020. The tire tread depth measurements at the time of the crash met federal requirements.[17] The bus passed an annual inspection on September 2, 2020, conducted by the THP's Commercial Vehicle Unit, Pupil Transportation Section. At the time of the crash, no recalls for this vehicle had been reported in the NHTSA recall database.

Daimler Trucks North America (Daimler), the manufacturer of the school bus, has determined that certain Thomas Built Saf-T-Liner HDX school buses (model years 2011–2021) do not fully comply with the requirements of Federal Motor Vehicle Safety Standard (FMVSS) 222, "School Bus Passenger Seating and Crash Protection"

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[14] According to 49 *CFR* 393.75, minimum tread depth for tires on the steer axle is 4/32 of an inch; it is 2/32 of an inch for tires on other axles.

[15] The data from the ECM were downloaded by a third-party consulting firm technician under the direction of the THP on November 4, 2020. A copy of the data was provided to the NTSB.

[16] The threshold for a sudden deceleration, which triggers a deceleration occurrence, is set as a 9 mph/s change in speed.

[17] See 49 *CFR* 393.75 for more detail.

([49 *CFR* 571.222](49 CFR 571.222)).[18] The noncompliance is with paragraph S5.2.3, "Barrier Performance Forward," and is related to the energy a barrier can absorb during an emergency event and the rate at which such energy can be absorbed. This applies to about 7,600 school buses, including the bus involved in this crash. On August 10, 2022, NHTSA determined that the noncompliance of the passenger-side barrier (partition) is "not inconsequential to motor vehicle safety." Therefore, in accordance with federal regulations, Daimler is required to provide notification of and free remedy for the noncompliance. Daimler is determining a plan for repair and intends to notify customers in October 2022.[19]

The bus had a driver seat and 13 rows of passenger seats on each side. Each row of seats was designed to accommodate up to three passengers, with a maximum seating capacity for 78 passengers. The two front row seats had 45-inch-tall vertical privacy partitions mounted in front of them. The bus had a bi-panel folding loading door at the right front, an emergency exit door just aft of the middle left-side of the bus, an emergency exit window at the back, one emergency exit window on the left side and two on the right side, and two emergency roof hatches.[20] The bus was equipped with a lap/shoulder belt for the driver but was not equipped with passenger lap or lap/shoulder belts.

Damage. The bus had severe crash damage across the front, as shown in figure 8. Figure 9 shows that the damage on the left side of the bus was concentrated in front of the steering axle. The left A-pillar along with the top of the windshield were displaced rearward beyond the driver's seating position. In addition, the driver-side window and the two front passenger windows on the left side were missing. On the right side of the bus (also figure 9), the entrance door and frame assembly were crushed rearward, preventing the use of the step well to enter or exit the bus. Glass panes were missing from the first and fourth passenger window frames on the right side. The rear of the bus was undamaged.

[18] See Daimler Trucks North America, LLC, Denial of Petition for Decision of Inconsequential Noncompliance, Notice, August 10, 2022 (87 *Federal Register* 48752, Docket No. NHTSA-2020-0005, Notice 2*)*. See https://www.federalregister.gov/documents/2022/08/10/2022-17132/daimler-trucks-north-america-llc-denial-of-petition-for-decision-of-inconsequential-noncompliance.

[19] For more information, see Part 573 Safety Recall Report at https://static.nhtsa.gov/odi/rcl/2022/RCLRPT-22V634-6187.PDF.

[20] The seat adjacent to the left-side emergency exit door was equipped with a flip-up seat pan to accommodate evacuation.

Figure 8. School bus front damage.

Figure 9. Crash damage to the driver side and right side of the school bus.

The dashboard was displaced about 2 feet rearward into the driver compartment and the loading area. The bus's rear-vision mirror, which was mounted on the inside of the roof at the center, was cracked and displaced rearward touching the right-side partition. The upper and inboard portion of the right-side partition was displaced less than 1 inch. The driver seat was found displaced aft, in contact with the driver-side partition. There was sidewall buckling at the driver-side partition and intrusion at the first row of passenger seats behind the driver. Also, the front row passenger seat on the driver side was deformed and displaced. Deformation was also noted to the seats in rows 2, 10, and 11 on the driver side of the bus. On the right side, the seat cushions of rows 8 and 10 were displaced and found in the footwells. The seatback of row 8 on the right side was deformed.

Investigators were unable to perform a functional test of the steering system, instrument panel, and braking system due to the extensive crash damage.

Vehicle-Recorded Data. The bus was equipped with a Cummins ISB6.7 engine and controlled by an ECM.[21] The data report indicated that the ECM's sudden deceleration event data parameter was not enabled. Thus, no sudden deceleration occurrences had been recorded since the bus had been in operation. According to the manufacturer, on Thomas Built school bus engines for model years 2010–2012, the sudden deceleration feature was disabled as a default setting from the factory. No evidence suggests that the bus manufacturer or the bus owner changed the setting.

1.5 Highway Information

1.5.1 General Information

The crash occurred in the southbound travel lane of SR-58 at mile marker 8.19, about 9.5 miles southeast of Decatur, Meigs County, Tennessee, and about 35 miles northeast of Chattanooga, Tennessee. This segment of SR-58 has two opposing, 12-foot-wide lanes of traffic delineated by solid double yellow lines. The horizontal alignment near the crash site consisted of a 900-foot-radius right curve with a 0.56% upgrade slope for motorists traveling in the northbound travel direction. Adjacent to the northbound and southbound travel lanes were paved shoulders. The east-side paved shoulder was about 1 foot wide. A solid white line denoted the shoulder from the travel lane. Milled rumble stripes, 8 inches wide by 7 inches long with an approximate depression of half an inch, existed in the paved shoulders.[22] They consisted of repeating sections of rumble stripes about 60 feet long with a gap of 15 feet between the sections.[23] The road had no centerline rumble stripes. Adjacent to the edge of the northbound paved shoulder was a v-ditch that consisted of a

[21] The data from the ECM were downloaded by a third-party consulting firm technician under the direction of the THP on November 4, 2020. A copy of the data was provided to the NTSB.

[22] A *rumble strip* is typically applied on freeways or facilities with shoulders 8-feet or wider and is offset from the pavement edge line by about 12 inches. A *rumble stripe* is typically applied on state highways with narrow shoulders 0- to 2-feet wide.

[23] Tennessee Code Annotated 55-8-175 provides that every person riding a bicycle has the rights and duties applicable to a vehicle driver on any public road in Tennessee. As such, the 15-foot gap pattern is provided on all non-controlled access facilities to accommodate bicyclists and meets TDOT standards. For more information, see T-M-16 Rumble Stripe Installation Layout at T-M-16 (tn.gov) (accessed August 10, 2022).

foreslope and backslope, which will be described in further detail later in this section. A curve right advisory sign was located about 1,320 feet before the crash site for the northbound travel lane and a curve left advisory sign was located about 422 feet before the crash site for the southbound travel lane. There was also a 55-mph speed limit sign next to the southbound travel lane. Figure 10 shows the view and cross-section of SR-58 in the northbound direction near the location where the truck's right tires left the roadway, with the crash site in the background.

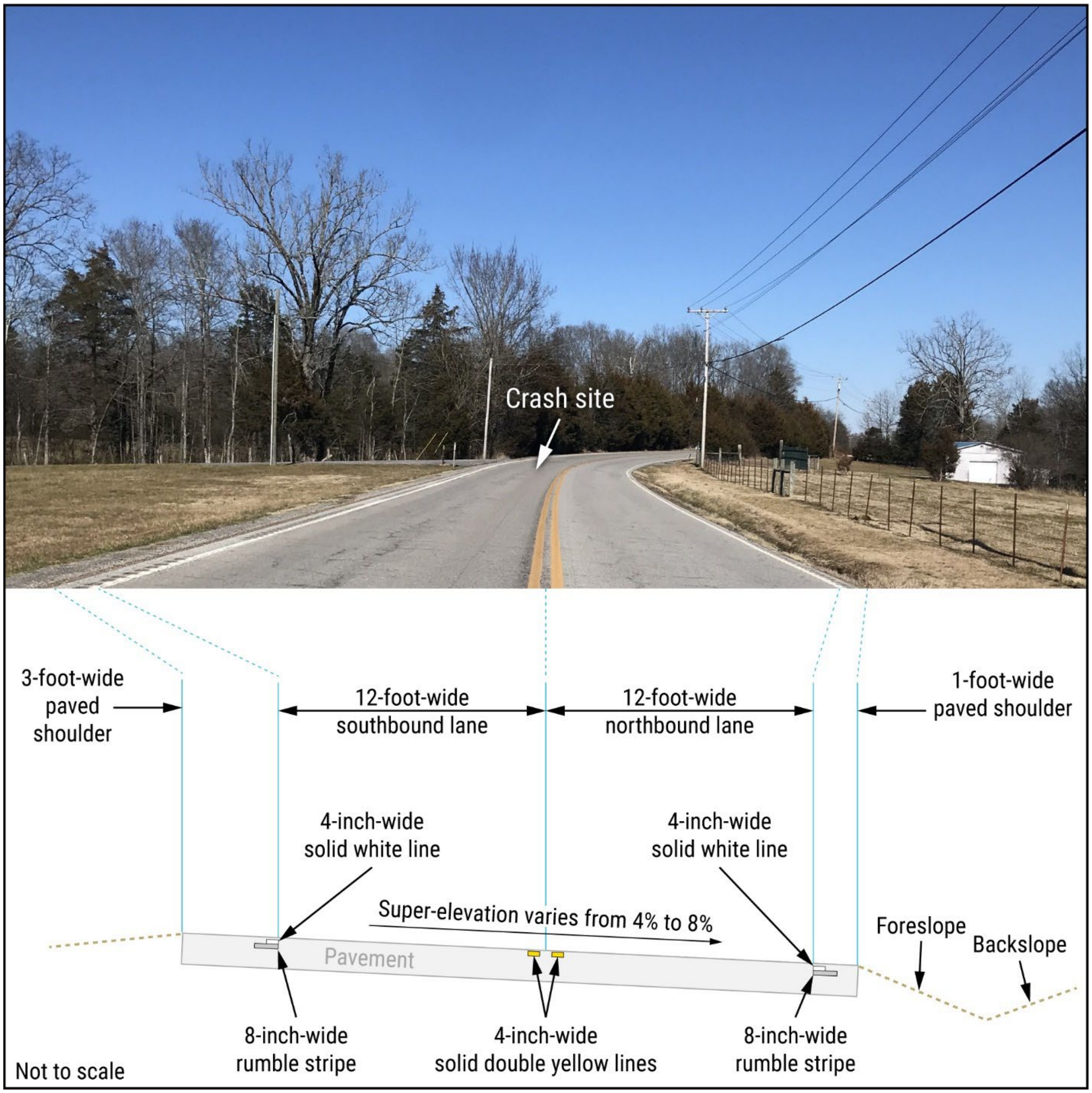

Figure 10. View and cross-section of SR-58 in the northbound direction with the crash location in the background. (Photo source: THP)

Figure 11 shows a close-up and cross-section of the earthen v-ditch with the truck's tire impressions on the foreslope, as shown by the red arrow.

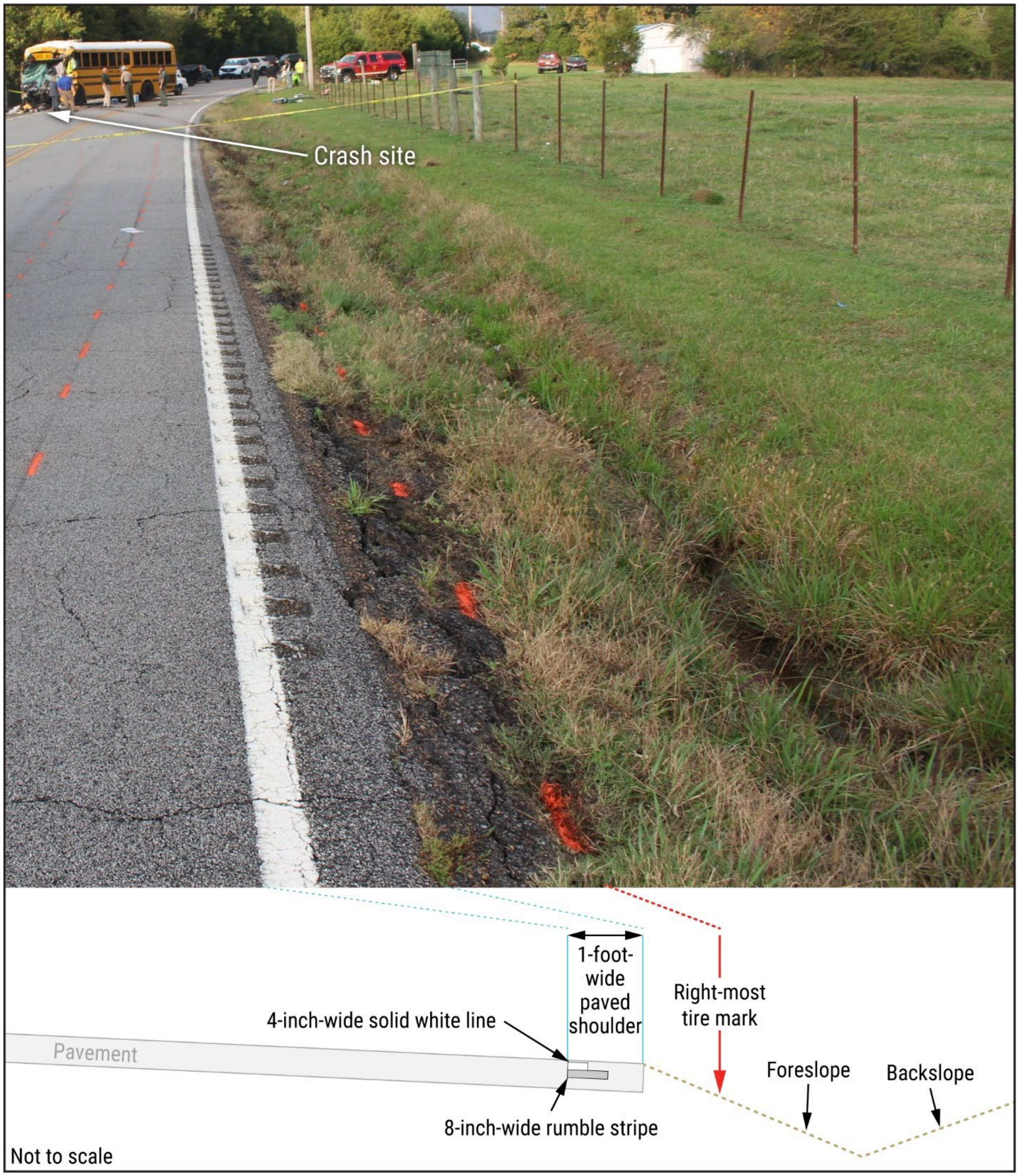

Figure 11. Close-up of v-ditch. (Photo Source: THP)

Postcrash, TDOT surveyed SR-58 at 20-foot increments to determine the approximate location of the truck's right-most tire mark, the classification of the foreslope, and the height of the pavement edge drop-off. The survey locations are shown in figure 12 (marked by numbers 1 through 12) and the corresponding information is summarized in table 2.

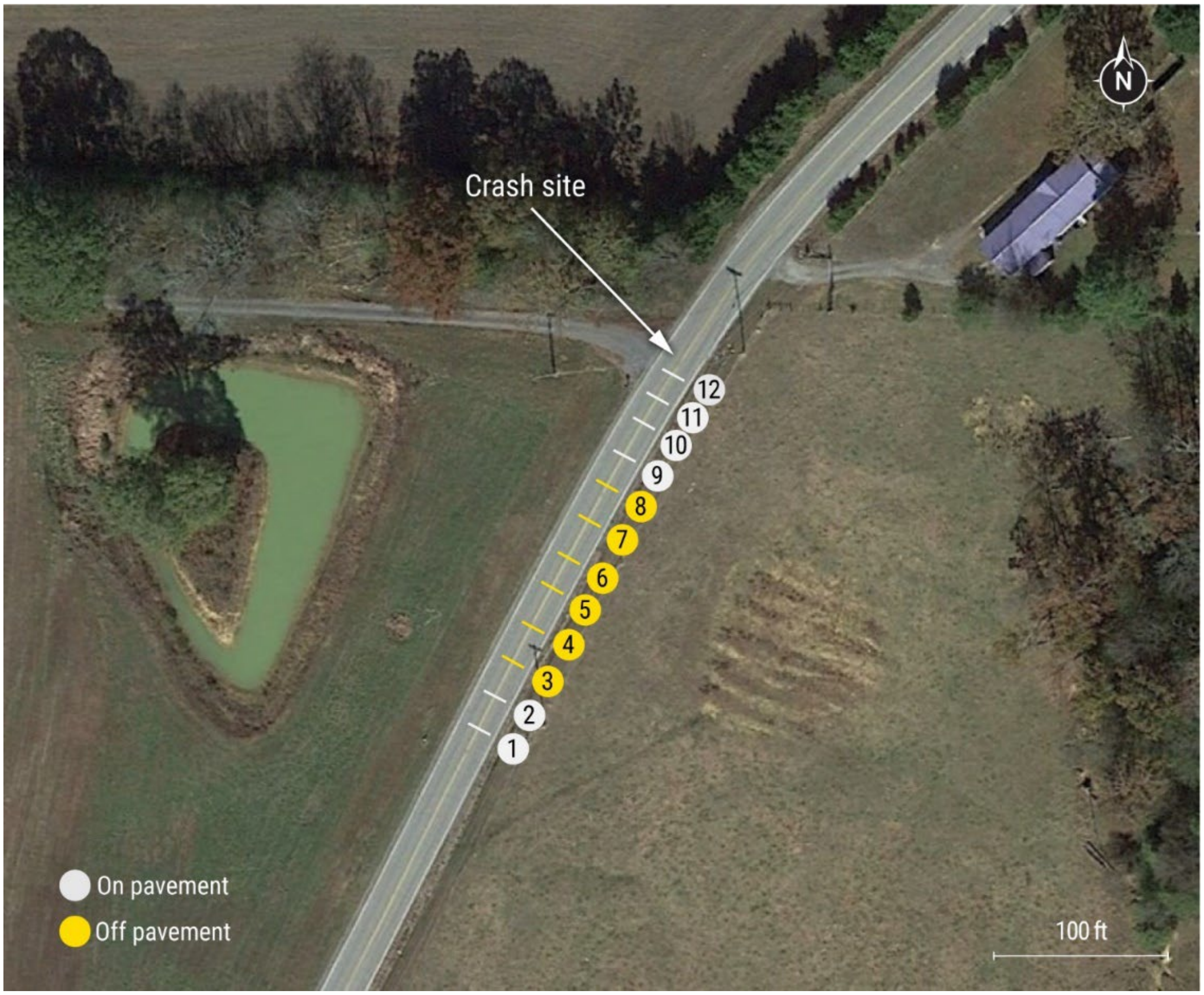

Figure 12. Aerial photo of SR-58 at the crash site, with overlaid markers. The yellow numbers indicate locations where the right-most tire mark was found in the earthen v-ditch, and the white numbers indicate that the truck's right-most tire mark was located on the pavement.

Table 2. Foreslope classification and pavement edge drop-off measurements along the northbound lane of SR-58.

Measurement location	Right-most tire mark on foreslope or pavement	Distance of right-most tire mark from edge of paved shoulder (feet)	Foreslope[a] (Vertical: Horizontal)	Classification of foreslope	Pavement edge drop-off (inches)
1	Pavement	N/A	1:2	Critical	2.5
2	Pavement	N/A	1:1.7	Critical	2.5
3	Foreslope	0.67	1:2	Critical	2.25
4	Foreslope	1.52	1:2	Critical	<1.75
5	Foreslope	1.54	1:3	Non-Recoverable	2.0
6	Foreslope	1.38	1:3	Non-Recoverable	1.75
7	Foreslope	1.33	1:3	Non-Recoverable	<1.75
8	Foreslope	0.52	1:3	Non-Recoverable	2.0
9	Pavement	N/A	1:2	Critical	<1.75
10	Pavement	N/A	1:3	Non-Recoverable	<1.75
11	Pavement	N/A	1:3	Non-Recoverable	<1.75
12	Pavement	N/A	1:3	Non-Recoverable	<1.75

[a] A 1:2 foreslope is commonly referred to as 1-foot vertical for every 2-foot horizontal distance.

The foreslope is the portion of the v-ditch that slopes down and away from the roadway toward the bottom of the v-ditch. AASHTO classifies foreslopes as either *recoverable*, *non-recoverable*, or *critical*. A *recoverable* slope is a slope on which a driver can stop or slow a vehicle enough to return to the roadway safely and is described by AASHTO as having a slope of 1V:4H or flatter (that is, the slope is 1 foot vertical over 4 feet horizontal distance). AASHTO describes a *non-recoverable* foreslope as one that is traversable but from which most vehicles will not be able to stop or return to the roadway easily. Foreslopes between 1V:3H and 1V:4H fall into this category. Vehicles on a *critical foreslope* have a higher propensity to overturn. Those slopes are steeper than 1V:3H. The foreslopes in the area of the lane departure were classified as critical and non-recoverable, as shown in table 2.

The pavement edge drop-off measurements refer to the vertical drop between the paved shoulder and the unpaved shoulder of the northbound travel lane. TDOT found that 5 of the 12 measurements were greater than 1.75 inches; all pavement edge drop-offs measured 2.5 inches or less.[24] Pavement edge drop-offs can make it difficult for drivers to return their vehicles to the pavement (also see section 1.9.3 Postcrash Actions in this report).

[24] No guidance exists for pavement edge drop-offs between paved and unpaved shoulders. TDOT recommends that the drop-offs be improved when the vertical edge drop-off between a paved travel lane and a paved shoulder exceeds 1.75 inches. AASHTO provides guidance for pavement edge drop-offs between a paved roadway and a paved shoulder with a difference of 3 inches or greater.

1.5.2 Crash History and Traffic Information

According to TDOT, data from 2015 to 2019 showed that about 4,200 vehicles traveled daily on SR-58 near the crash site. Most of the vehicles (96%) were passenger cars. The Meigs County School District informed the NTSB that on a regular school day, 7 school buses traveled northbound in the morning and 7 school buses traveled southbound in the afternoon. From 2015 to 2020, one other fatal crash, 5 injury crashes, and 19 property damage crashes occurred within a 2-mile segment north and south of the crash location.[25]

1.5.3 Maintenance

SR-58 near the crash site was constructed in 1928 as a rural two-lane undivided roadway. It was resurfaced in 2011 and in June 2020 had been placed on TDOT's resurfacing schedule with a proposed time frame of 2022 (see section 1.9.3 Postcrash Actions for additional information).

1.6 Driver Information

1.6.1 Service Truck Driver

Employment and Licensing. The 56-year-old truck driver was employed by SEC as a mechanic since March 2019. His duties included servicing and repairing the company's vehicles. At times, he was required to operate the service truck involved in this crash to travel to repair vehicles.

The truck driver held a Tennessee Class A commercial driver's license (CDL) with endorsements to tow double/triple trailers and operate tank vehicles. The driver's current CDL had been issued in December 2018 with an expiration date of December 2026. According to his SEC application, he had a CDL since March 2004 and had held at least four other jobs requiring a CDL. The Commercial Driver's License Information System (CDLIS) showed no convictions for traffic offenses or previous traffic crashes in Tennessee.

Medical and Toxicology Information. The truck driver's Department of Transportation (DOT) medical certificate was issued on June 23, 2020, and had a duration of 1 year due to his diabetes. According to reviewed medical certification and primary care records, the truck driver's medical conditions included type 2

[25] The fatal crash occurred on August 24, 2020, in which a northbound vehicle made a left-hand turn onto an intersecting road and crossed into the travel path of a southbound vehicle. The intersection was located about 4,300 feet south of the crash location.

diabetes treated with metformin and dulaglutide, obstructive sleep apnea (OSA) treated with continuous positive airway pressure (CPAP) therapy, and high blood pressure and high cholesterol treated with medications.

During an interview with the NTSB, the driver stated that he had been using his CPAP machine regularly, typically for about 8 hours per night.[26] A CPAP usage report for the period January 19, 2019, through February 12, 2020, indicated that the driver used the CPAP machine 98% of those days, with an average use of 7 hours 38 minutes per day. No precrash CPAP usage data were available after February 12, 2020.[27]

The Tennessee Bureau of Investigation Nashville Crime Laboratory and the Federal Aviation Administration Forensic Sciences Laboratory performed toxicological testing of blood collected from the service truck driver about 2 hours after the crash. Both laboratories detected doxylamine at levels too low to directly quantify.[28] Doxylamine is a sedating antihistamine medication available over the counter as a sleep aid and as an ingredient in various cold and allergy products. No other potentially impairing tested-for substances were identified by either laboratory. At the request of the NTSB, the Federal Aviation Administration Forensic Sciences Laboratory measured the driver's hemoglobin A1c (HbA1c) and found it to be 10%.[29] DOT postaccident drug and alcohol testing was performed the day after the crash and did not detect any tested-for substances.

Activities Before the Crash. A 4-day work/rest history was recreated for the truck driver based on the THP and NTSB interviews, his cell phone records, and SEC electronic time records (see table 3).[30] According to SEC's time records for the 8 days before the crash, he was in compliance with hours-of-service regulations. His normal work week schedule consisted of four 10-hour shifts with a 30-minute break, from

[26] The THP interviewed the truck driver on October 27, 2020, and the NTSB conducted a follow-up interview on December 14, 2021, to obtain additional medical information.

[27] The NTSB requested these additional records in February 2022.

[28] Doxylamine typically exerts its desired medicinal effects at levels between about 50 ng/mL and 200 ng/mL in blood (Schulz and others 2020). The quantities detected by both laboratories were less than 50 ng/mL. According to an e-mail from the Federal Aviation Administration Forensic Sciences Laboratory, "too low to quantify" means that the doxylamine level was less than half of the low end of the range in which the drug typically exerts its desired medicinal effects. (Also see sections 2.1 and 2.2.)

[29] HbA1c is an indirect measure of a person's average blood sugar over the preceding approximately 3 months. In general, HbA1c of less than 7% indicates good control of diabetes.

[30] The truck driver was operating under an exemption to the hours-of-service rules for short-haul operations (49 *CFR* 395.1) and was not required to track hours of service with an electronic logging device. However, his employer (SEC) is required to maintain time records for its drivers.

7:00 a.m. to 5:30 p.m. According to his interview with the THP, the truck driver said that the night before the crash he watched television and went to bed between 8:00 p.m. and 9:00 p.m. He woke up between 5:00 a.m. and 5:30 a.m. on the day of the crash, did a pre-trip inspection on his truck, and traveled first to SEC outside Chattanooga (about 60 miles). During the day, he also traveled toward Altamont, Tennessee (about 60 miles) to replace a company radio in a utility service truck, then to Ooltewah, Tennessee (about 70 miles), where he worked on another truck. On the afternoon of the crash, the truck driver was traveling through Decatur on SR-58 to check on the crews and their vehicles on his way home. He told the NTSB that he was not in a hurry. In both interviews (NTSB and THP), he said he was looking in his side rear-vision mirrors at the sheriff's deputy vehicle traveling behind him when the truck edged off the roadway. He said he intended to keep the vehicle straight, and he slowed down by letting up on the accelerator to "ride it out." He said the truck "shot back across the road" and that was the first time he saw the yellow school bus. He told the NTSB that he had driven on that road "hundreds of times" and was aware of the steep ditch in that area.

According to the THP police report, the truck driver had a personal cell phone and a work cell phone in his possession. The work cell phone records showed an outgoing call at 1:44 p.m. and an incoming text at 2:06 p.m. The personal cell phone records indicated an outgoing phone call at 1:41 p.m., an outgoing text at 3:25 p.m., and an incoming text at 3:50 p.m., 5 minutes after the crash occurred. The phone records suggested that the truck driver's work phone was used during on-duty time, and his personal cell phone record showed no night-time calls, texts, or movement during his sleep time.

Table 3. Activities of truck driver.

Date	Hours worked during the day	Time of first cell phone movement[1]	Time of last cell phone movement
Saturday, October 24, 2020	Off-duty	9:00 a.m.	9:00 p.m.
Sunday, October 25, 2020	Off-duty	7:10 a.m.	10:00 p.m.
Monday, October 26, 2020	12 hours on-duty	7:26 a.m.	9:15 p.m.
Tuesday, October 27, 2020	About 9.75 hours on-duty	6:50 a.m.	Crash occurred at 3:45 p.m.

[1]Indicates cell phone movement according to GPS data on personal cell phone.

1.6.2 School Bus Driver

Employment and License History. The 53-year-old female driver had been employed as a school bus driver with Meigs County School District since July 2018. From July 2017 to July 2018, she worked as a school bus driver for the City of Cleveland, Tennessee. She held a valid Tennessee Class B CDL with endorsements to operate school buses and carry passengers. Her license was issued in October 2017 and due to expire October 2025. CDLIS showed no convictions for traffic offenses or previous traffic crashes in Tennessee, and motor vehicle records indicate a property damage-only incident in 2019; no further information was listed to determine whether that incident occurred in her personal vehicle or a commercial one.

Medical and Toxicology Information. The school bus driver's DOT medical certificate was issued on June 5, 2020, with a duration of 1 year because the Tennessee State Board of Education rules require school bus drivers to complete physical examinations annually.[31] At her commercial motor vehicle driver medical examination on that date, she reported taking lisinopril to treat high blood pressure, omeprazole to treat acid reflux, and gabapentin to treat fibromyalgia. According to her autopsy report, her cause of death was multiple blunt-force injuries. The autopsy did not identify significant natural disease. Postmortem toxicological testing detected

[31] In accordance with Tennessee Code, the Tennessee State Board of Education rules require school bus drivers to complete annual physical examinations.

duloxetine, gabapentin, promethazine, eszopiclone/zopiclone, caffeine, nicotine, cotinine, and meloxicam. Of these substances, duloxetine, gabapentin, promethazine, and eszopiclone/zopiclone are potentially impairing.[32]

Activities Before the Crash. The school bus driver worked a regular, split-shift schedule. She worked during the mornings from 6:45 a.m. until 8:00 a.m. and during the afternoons from 2:45 p.m. until 4:30 p.m. On the day of the crash, she had also driven her morning route. The THP did not download her cell phone activity; thus, the NTSB was unable to develop a record of her opportunity for rest and cell phone use.

1.7 Motor Carrier Operations and Regulatory Oversight

1.7.1 Service Electric Company

SEC is an electrical contractor specializing in the construction and maintenance of electric transmission and distribution systems. It is a subsidiary company of Quanta Services Incorporated of Houston, Texas. SEC is registered as an interstate carrier of private property. According to the carrier's Motor Carrier Identification Report, SEC employed 1,143 drivers and operated 936 trucks. The company has been in business since 1948.

In addition to receiving training on personal protective equipment, defensive driving, and general safety, all new employees whose job duties include driving a vehicle requiring a CDL received a transportation safety review covering CDL rules, interstate and intrastate issues, restrictions, and use of cellular phones. Company records indicated that the truck driver completed this training in March 2019.

SEC maintained safety policies and programs for accident reporting, controlled substance and alcohol testing, seat belt use, distracted driving, and safe driving. It used a fleet management software program to track vehicles, speed, and routes via GPS.[33] Using the information from the fleet management system, drivers

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[32] Duloxetine is a prescription medication commonly used to treat depression and anxiety. Other uses include treating fibromyalgia and certain types of pain. Gabapentin is a prescription medication commonly used to treat nerve pain and certain types of seizures. It may also be used to treat fibromyalgia. Promethazine is a prescription medication that can be used as a sleep aid, as well as to treat nausea and vomiting, motion sickness, allergy symptoms, and hives. Eszopiclone is a prescription medication used to treat insomnia. Caffeine is a central nervous system stimulant. Nicotine is a chemical that is found in tobacco products, electronic cigarette liquid, and certain smoking cessation aids. Cotinine is a metabolite of nicotine. Meloxicam is a prescription medication commonly used to treat arthritis pain and inflammation. See the medical factual report in the docket for additional information on these drugs.

[33] Data from the fleet management system for the day of the crash did not show any speed violations on the truck's route.

performing poorly as indicated by hard braking or speeding incidents would receive feedback to improve driving performance. No evidence indicated that the truck driver had received feedback for his driving performance.

The carrier's most recent Federal Motor Carrier Safety Administration (FMCSA) compliance review rating before the crash was satisfactory and was conducted in 2005. Following the crash, an on-site focused review was conducted in January 2021 and no acute or critical violations were found. SEC underwent 109 roadside inspections from October 28, 2018, to October 28, 2020. The out-of-service rate for drivers was 0.0% and for vehicles 18.2%.[34] There were no roadside inspections involving the driver in this crash.

1.7.2 Meigs County School District

The Meigs County School District serves the Meigs County area of southeastern Tennessee. The school system has about 1,600 students in grades K–12 in four schools. At the time of the crash, the Meigs County School District employed 20 full-time and 7 part-time drivers and operated 20 school buses.

Among other requirements, Meigs County required all school bus drivers to be at least 25 years old, have a satisfactory driving record, maintain a valid Tennessee CDL with a passenger or school bus endorsement, successfully pass a background check, submit to preemployment and annual drug and alcohol testing, and have an annual medical examination. The school bus driver involved in the crash met these requirements.

The school district provides each driver with a transportation handbook outlining the driver's responsibilities and duties, route, and operations. Each year, drivers are required to attend a 4-hour driver safety training class sponsored by the THP to maintain their school bus endorsement. The Meigs County School District provides annual safety training to bus drivers that includes information on the proper seating position for all passengers. A component of the drivers' evaluation includes the drivers' enforcement of proper seating position of the passengers.

Meigs County Board of Education policy 6.308 addresses bus safety and conduct.[35] It provides guidelines for bus access and use, driver supervision and authority while on the bus, and the use of photographs and video footage from bus

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[34] The national driver out-of-service rate is 5.1% and the vehicle out-of-service rate 20.7%.

[35] For more information about Meigs County Board of Education Bus Safety and Conduct Policy, see https://tsbanet-my.sharepoint.com/:w:/g/personal/policy_tsba_net/EZ9xnnzMJgFNpgC8Fq56C0kBfUVCS5ax8dl48C8HzVwsaA?rtime=zNBvqfgT2kg (accessed July 26, 2022).

cameras. School bus drivers instruct students on bus safety including proper seating position. The Meigs County School District's website contains information for students and parents on safe transportation, including behavior on the bus.[36]

1.8 Weather

Weather data for October 27, 2020, was obtained from weather station KCHA at Chattanooga Lovell Field airport, located about 31 miles from the crash site. At 3:43 p.m., the station reported a temperature of 72°F, winds from the north-northwest at 4.6 mph, visibility of 10 statute miles, and no precipitation. According to the National Oceanic and Atmospheric Administration Solar Calculator, on October 27, 2020, the sunrise for Decatur was 7:57 a.m. and sunset was 6:49 p.m. At 3:45 p.m., the sun was at an azimuth of 221.21° from true north and an elevation of 30.9°.

1.9 Additional Information

1.9.1 Video Study

NTSB investigators reviewed video recordings from one outward-facing and two inward-facing wide-angle cameras from the school bus. The outward-facing camera was mounted on the windshield of the bus. The NTSB analyzed the recordings of the outward-facing camera to estimate the speed of the truck as 52±2 mph in the area where the truck's right tires departed the roadway. The last frame of the outward-facing video recording displayed the speed of the bus as 46 mph before impact. However, in the seconds before the crash its speed was 46–48 mph.

The outward-facing video camera showed the precrash movement of the truck. The truck departed the roadway; then, in less than 2.5 seconds, it returned to the roadway and crossed into the southbound travel lane. While the truck was off the road, the rear wheels slid down the foreslope as the front wheels tracked along the edge of the pavement (see figure 3).

The NTSB reviewed the footage captured by the two inward-facing cameras to determine passenger seating positions (see section 1.2) and passenger movement before impact. One of the inward-facing cameras was mounted above the driver's seat looking aft and captured portions of all passenger seats and a portion of the boarding door. The other camera was mounted above the last row of seats, pointed forward, and had a view of the last six rows of passenger seats. Neither inward-facing camera had a

[36] For more information about Meigs County School District's transportation, see https://core-docs.s3.amazonaws.com/documents/asset/uploaded_file/3230/MCS/2361598/Copy_of_a_students_guide_to.pdf (accessed August 16, 2022).

clear view of the driver. The footage showed several students out of position, such as facing aft or sideways in the aisle. Although the onboard video recording system did not record braking or steering inputs, occupant motion was examined to determine if the driver attempted any evasive action in response to the truck crossing the centerline. Inward-facing video footage showed that all the students were displaced forward simultaneously in the final second of the recording, indicating that the bus decelerated before impact. The recordings ended before impact.

1.9.2 Witness Statements

Sheriff's Deputy Behind the Truck. The Meigs County sheriff's deputy following behind the service truck said he had pulled out behind the truck from Lamontville Road (about 4,300 feet south of the crash site) on his way to respond to a non-emergency incident.[37] The deputy said he did not notice "anything out of the ordinary" about the truck until it partially went off the right side of the roadway.

Driver Immediately Behind the Bus. The witness traveling south on SR-58 immediately behind the school bus said that as he came around the turn, he saw the "white utility truck, two tires off the right side of the road, looked like he went to correct, lost it, ended up sliding across the oncoming lane into the front of the bus."[38]

Sheriff's Deputy Behind the Bus. The Meigs County sheriff's deputy following behind the school bus said he was traveling south on SR-58 and was two vehicles behind the bus.[39] He said he saw the service truck come out of the ditch and veer across the road in front of the bus. Following the crash, the deputy stopped to help the bus passengers. He said he saw the truck driver walking around after the crash also trying to help the passengers and described him as distraught.

1.9.3 Postcrash Actions

In June 2020, based on the pavement condition, SR-58 was forecast as a 2022 need project and added to the TDOT's 3-year list of proposed resurfacing projects.[40]

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[37] The deputy following behind the service truck was interviewed by the THP on October 28, 2020.

[38] The witness following behind the school bus was interviewed by the THP on October 27, 2020.

[39] The deputy behind the school bus was interviewed by the THP on October 27, 2020.

[40] TDOT calculates a pavement quality index value based on pavement distress and pavement smoothness. (For more detail, see Microsoft Word - 2021 PMS Draft Report_v0.2 (tn.gov)). According to TDOT, in 2020, the pavement quality index for this route was 2.61 (on a 5-point scale), above TDOT's trigger value of 2.5, and was forecast as a 2022 need, based on pavement condition.

Other factors were also considered in the resurfacing projects, and the proposed improvement project for SR-58 included the following:

- Resurfacing of the existing travel lanes and shoulders by removing the top 1.25-inch layer of pavement and replacing it with a new 1.25-inch layer of hot mix asphalt.
- New enhanced high-visibility pavement markings.
- Centerline snow plowable markers.
- Flush stabilized shoulders that eliminate the pavement edge drop-off. Proposed shoulder stones and Safety Edges℠ to be constructed adjacent to the paved shoulder edge.[41]
- Drainage improvements to the earthen v-ditch that reshape and flatten the foreslopes.

The shoulder work to flatten the foreslopes of the earthen v-ditch adjacent to the northbound lane near the crash site was completed on February 16, 2022. The foreslopes were flattened so that all locations were recoverable slopes (1V:4H or flatter). Construction on resurfacing the existing travel lanes and adding new enhanced high-visibility pavement markings, centerline snow plowable markers, and shoulder stone was expedited and completed in July 2022. In addition to adding the shoulder stone to portions of SR-58, TDOT built Safety Edges℠ to mitigate the pavement edge drop-offs.[42] Safety Edges℠ are frequently used to reshape the edges between a paved roadway and a paved shoulder to eliminate the vertical drop-offs and provide a transition for vehicles; they can also be used with unpaved surfaces as in this case. Figure 13 shows SR-58 before and after the TDOT 2022 improvement project was completed.

[41] The term *shoulder stone* is used by TDOT to describe a compacted aggregate shoulder adjacent to the paved shoulder. A shoulder stone is used to eliminate any vertical edge drop-off at the edge of the paved shoulder.

[42] For more information on the Safety Edge℠, see https://www.fhwa.dot.gov/innovation/everydaycounts/edc-1/safetyedge.cfm (accessed July 28, 2022).

Figure 13. Before and after depictions of the roadway with the flattened foreslopes and the addition of the shoulder stone and Safety Edge℠.

2. Analysis

2.1 Introduction

The 2018 Freightliner service truck was traveling north on SR-58 at an estimated speed of about 52 mph in Decatur, Meigs County, Tennessee. At the same time, the 2013 transit-style school bus was southbound on SR-58 traveling at 46–48 mph, carrying 33 students home from school. The truck driver reported that he was looking in his side rear-vision mirrors at a sheriff's deputy vehicle behind him when the truck's right-side wheels departed the right side of the roadway and entered the earthen v-ditch. When the truck re-entered the roadway, it yawed counterclockwise, crossed into the southbound lane, and was almost perpendicular to the roadway immediately before the school bus hit the right side of the truck. As a result of the crash, the bus driver and a student passenger were fatally injured. Fourteen students sustained serious or minor injuries.

This analysis first discusses those factors that could be excluded as not causing the crash or contributing to its severity. Then, the following safety issues are discussed:

- Inadequate roadway design of SR-58,
- Lack of lane departure warning and prevention systems for heavy vehicles, and
- Lack of sufficient passenger protection measures on school buses.

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

- *Mechanical condition of the service truck and school bus:* Postcrash inspection of the service truck did not find any failures of the steering, brake, or suspension systems. The damage to the tires and wheels on the right side of the vehicle resulted from the crash. Although crash damage precluded a thorough inspection of the bus's mechanical systems, visual inspection of the bus postcrash and a review of the maintenance records did not indicate any preexisting operational issues with the school bus. There were no open recalls for either vehicle.

- *Management safety practices of SEC and Meigs County School District:* Both SEC and Meigs County School District had practices and programs to promote safety. The hiring procedures and new employee training also incorporated safety requirements.

- *Service truck and school bus driver licensing, training, and experience:* The truck driver held a CDL, had been employed by SEC for 20 months before the crash, and had completed training as required by SEC. He had driven commercial vehicles previously and held a CDL since 2004. The school bus driver held a CDL with school bus and passenger endorsements, and had been driving a school bus for more than 3 years.

- *Alcohol and other potentially impairing drugs for the service truck driver:* The truck driver's postcrash alcohol testing was negative. The only potentially impairing drug detected in the truck driver's blood about 2 hours after the crash was doxylamine, which can cause sedation. Based on the toxicology results and on how slowly doxylamine is typically eliminated from the bloodstream, the level of doxylamine in the truck driver's blood at the time of the crash was likely below the range at which doxylamine typically exerts its desired medicinal effects (Schulz and others 2020). At such a low level, it is unlikely that doxylamine caused impairment affecting the crash.

- *Service truck driver's cell phone use and scheduling:* No evidence suggests that the truck driver was using a cell phone at the time of the crash. The truck driver stated that he worked a regular schedule with sufficient off-duty time for rest. He was in compliance with the FMCSA's hours-of-service regulations.

- *Weather:* Visibility was clear and the roadway was dry.

- *Emergency response:* Two deputies were traveling behind the crash-involved vehicles, witnessed the crash, and provided assistance immediately. Within 7 minutes of being notified of the crash, additional police and fire/rescue personnel arrived on-scene. All injured passengers were transported from the scene by either ground or air within 65 minutes after the crash notification. The uninjured bus passengers were transported by bus from the crash site within 25 minutes of the crash.

Therefore, the NTSB concludes that none of the following were factors in this crash: (1) mechanical condition of the service truck or school bus; (2) management safety practices of SEC and Meigs County School District; (3) service truck and school bus driver licensing, training, and experience; (4) alcohol and other potentially impairing drug use; (5) the service truck driver's cell phone use or schedule; or (6) weather. The NTSB further concludes that the emergency response to the crash was timely and effective.

The truck driver had OSA, a medical condition that might affect the quality of rest. If inadequately treated, OSA may lead to excessive daytime sleepiness and fatigue, decreased alertness, and cognitive and motor impairment (Kline 2021; Décary and others 2000). Inadequately treated OSA increases the risk and severity of motor vehicle crashes (Tregear and others 2009; Mulgrew and others 2008; FMCSA 2007). Effective CPAP treatment reduces that risk (Marimi and others 2015; Tregear and others 2010). Medical records showed that the truck driver's CPAP adherence between January 2019 and February 2020 was excellent overall, consistent with the regular CPAP usage that he reported in his interview. However, at the time of the NTSB request for CPAP usage records in February 2022, no records were available to assess his CPAP usage during the weeks immediately before the crash, so whether his OSA was adequately treated during that time could not be determined. In his interview, the truck driver said he used his CPAP machine nightly and even took it on travel with him.

The truck driver also had diabetes treated with medication. His HbA1c of 10% indicates that his blood sugars were running high on average in the months leading up to the crash, but the HbA1c does not indicate his immediate blood sugar at the time of the collision. Based on information that he was observed to be driving unremarkably before the lane departure and was walking around trying to help passengers immediately after the crash, it is unlikely that he was experiencing severe diabetes-related impairment from major metabolic disturbance or extreme low blood sugar at the time of the crash. Less-severe potentially impairing diabetes-related symptoms such as blurry vision or fatigue cannot be excluded from available medical evidence. The NTSB concludes that no available evidence suggests that the truck driver's diabetes or OSA contributed to the crash.

2.2 Driver Response

2.2.1 Truck Driver Actions

Run-off-the-road crashes are often attributed to driver-related factors, such as driver inattention, driver fatigue, alcohol use, driver unfamiliarity with the roadway, physical or mental health conditions, stress, and being in a hurry (NHTSA 2011). However, many of these factors have already been excluded in this crash. The NTSB did not find any evidence of cell phone use by the truck driver at the time of the crash, and his postcrash alcohol test results were negative. He was familiar with the roadway and even said that he was aware of the steep ditch on the shoulder. He stated he was not in a hurry, and analysis of video evidence indicated that he was not speeding.

As the truck traveled on SR-58, a sheriff's deputy vehicle turned onto the road behind the truck. The distance between the road from which the sheriff's deputy vehicle turned onto SR-58 to where the truck departed the road is just under 4,100 feet, and it would have taken about 54 seconds to travel that distance at an estimated speed of 52 mph. The truck driver said he was looking back at the sheriff's vehicle through his mirrors before departing the roadway. Glancing in mirrors is part of the driving task and the Tennessee CDL Manual instructs drivers to check their mirrors regularly (Tennessee Department of Safety and Homeland Security 2017). The manual also states:

> When you use your mirrors while driving on the road, check quickly. Look back and forth between the mirrors and the road ahead. Don't focus on the mirrors for too long. Otherwise, you will travel quite a distance without knowing what's happening ahead.

Research has found that objects external to the vehicle can take the driver's attention from the forward roadway and increase crash risk. External objects may include vehicles on the shoulder of the road, billboards, and animals. A 100-car naturalistic driving study conducted by the Virginia Tech Transportation Institute found that attending to external objects away from the forward roadway for more than 2 seconds increased the risk of accidents threefold (Klauer and others 2006). The AAA Foundation for Traffic Safety examined NHTSA's National Automotive Sampling System/Crashworthiness Data System and found that 29% of distraction-related crashes were due to factors outside of the vehicle (Stutts and others 2001). An FMCSA-funded naturalistic study of commercial vehicle operators found that although glances outside the vehicle had an overall protective effect, long glances away from the forward roadway when an external distraction was present increased the risk of a safety-critical event (Olson and others 2009).[43] Overall, the study found that glances away from the forward roadway for any reason for more than 1.5 seconds significantly increased the risk of a safety-critical event.[44]

In this case, the external target was the sheriff's deputy vehicle traveling behind the service truck. The presence of police or law enforcement can influence driver behavior. An Australian field study showed that the presence of a stationary police vehicle on an urban road reduced the percentage of speeding vehicles by two-thirds; however, drivers resumed their normal driving behavior soon after passing the vehicle (Armour 1986). Similarly, a study conducted on a US highway showed that the average vehicle speed was reduced approaching a police vehicle but accelerated to normal speed after passing the police vehicle (Sisiopiku and Patel 1999). Anecdotal stories suggest that when a police vehicle is nearby, drivers "brake" or "slow down" even when they have not done anything wrong (Paulas 2017). These behaviors are

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[43] A *safety-critical event* is defined as crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations.

[44] For glances between 1.5 and 2 seconds, overall risk equals 1.29. For glances greater than 2 seconds, overall risk equals 2.93.

explained by deterrence theory; that is, people avoid behaviors because they fear the consequences of getting caught (Sam 2022).

The truck driver engaged in a driving-related action when he looked in his mirrors at the sheriff's deputy vehicle traveling behind him, exhibiting behavior that is not unusual. Although it is not known the length of time the driver's attention was drawn away from the forward roadway, the sheriff's deputy vehicle traveled behind him for nearly a minute by the time the truck departed the roadway, providing plenty of time for an extended glance to increase the crash risk. The NTSB concludes that the truck driver failed to keep his vehicle on the roadway due to his inattention to the forward roadway when he was looking at the sheriff's deputy vehicle behind him.

After departing from the road, the truck continued traveling with its right wheels off the roadway for 139 feet before the front right wheel returned to the roadway. The driver said he was aware of the steep ditch and tried to keep the truck straight after the right-side wheels dropped off the roadway but the truck "shot back across the road." The video footage showed movement of the steer (front) axle, indicative of steering, and soil displacement by the right rear tires, indicative of continued wheel rotation. The NTSB concludes that in response to unintentionally driving off the roadway, the truck driver steered the truck toward the left; as the truck's right front wheel returned to the roadway the truck yawed counterclockwise.

2.2.2 School Bus Driver Actions

Analysis of the video from the outward-looking camera on the school bus indicated that the bus driver had just slightly more than 2 seconds before impact to detect the truck's movement back to the roadway toward the southbound lane, and to interpret the movement as a possible hazard and initiate braking. Studies have shown that driver reaction times vary and can range from less than a second for expected events to 1.5 seconds for surprise events (Green 2000). However, many other factors like the complexity of the response or cognitive workload can influence the driver's reaction time. Further, the reaction time estimates do not account for the stopping time of the vehicle. In this case, the school bus driver had less than 2.5 seconds to recognize and interpret the truck as a hazard as it re-entered the roadway, crossed the northbound travel lane into the southbound lane, and to initiate braking to stop the large, heavy school bus. The inward-facing cameras indicated that she reacted to the truck crossing into the bus's travel lane by braking, as shown by the forward movement of the passengers before the impact with the truck. The NTSB concludes that although the school bus driver had time to react to the truck crossing into her travel lane, she did not have enough time to avoid the collision.

The school bus driver had a medical condition (fibromyalgia) and had used medications (duloxetine, gabapentin, promethazine, and eszopiclone) that had the potential to impair driving performance. Although she worked a regular schedule, her opportunity for rest could not be determined nor could her cell phone activity. Despite the lack of information regarding fatigue, cell phone distraction, and potential impairment due to medications, video evidence showed that the school bus driver identified and responded to the hazard presented by the service truck in a timely manner and initiated braking to reduce the bus's speed. The NTSB concludes that the school bus driver reacted quickly by braking when the service truck crossed over into the bus's travel lane; therefore, factors such as her medical conditions, her use of medications, and the potential for fatigue or distraction likely did not contribute to the crash or its severity.

2.3 Roadway Design

The section of SR-58 where the collision occurred has two opposing, 12-foot-wide lanes of traffic delineated by solid double yellow lines. In the area where the truck departed the right side of the road, the 1-foot-wide paved shoulder included a 4-inch-wide solid white line with 8-inch-wide rumble stripes. Adjacent to the edge of the northbound paved shoulder was a v-ditch.

The foreslopes of the v-ditch where the truck's right wheels were off the roadway were classified as either non-recoverable or critical, depending on the location.[45] According to AASHTO, most vehicles will not be able to return to the roadway easily on non-recoverable foreslopes, and there is a high propensity for vehicles to overturn on critical foreslopes. The video showed the right rear wheels sliding down the foreslope, which indicates the inability of the right rear tires to maintain traction on the slope.

In addition to the recovery challenges posed by the critical and non-recoverable foreslopes, returning to a roadway can be even more difficult when there is a vertical difference at the pavement edge, such as between the paved shoulder and the unpaved shoulder. AASHTO notes that it is not unusual for an unstabilized shoulder to consolidate and become lower than the roadway, and "the drop-off can adversely affect driver control when driving onto the shoulder at any appreciable speed."

Of the 12 measurements taken between the paved edge of the shoulder and the unpaved shoulder along this section of roadway, 5 indicated that the pavement

[45] The foreslopes of the earthen v-ditch in the area before the truck departed from the road and in the area after it returned to the road were also classified as critical and non-recoverable.

edge drop-off exceeded 1.75 inches at the edge of the paved shoulder.[46] TDOT recommends that the pavement edge drop-off be improved when the vertical drop-off exceeds 1.75 inches between the paved travel lanes and paved shoulder. The NTSB concludes that the truck driver's ability to safely return to the roadway was affected negatively by the non-recoverable and critical foreslopes of the earthen v-ditch and the height of the pavement edge drop-off, which contributed to the vehicle yawing as it returned to the roadway.

In February 2022, TDOT completed an improvement project of the earthen v-ditch adjacent to the northbound lane near the crash site to reshape and flatten the foreslopes. In July 2022, TDOT also added shoulder stones and Safety Edge[SM] to eliminate the vertical drop-off edge at the paved shoulder. The NTSB concludes that the TDOT improvement project to reshape and flatten the foreslopes of the earthen v-ditch and to eliminate the pavement edge drop-off will provide drivers who leave the roadway a better opportunity to regain control of their vehicle.

2.4 Preventing Lane and Roadway Departure Crashes

Prevention of lane and roadway departure crashes can be addressed using both highway and vehicle technologies. Rumble strips are milled or raised elements of a paved road generally placed at lane or roadway edges so that when a driver crosses the lane or roadway edge, they are alerted through both auditory and tactile vibration (National Cooperative Highway Research Program 2009). The driver then can attempt to take corrective steering action.[47] As such, rumble strips are an effective countermeasure for reducing roadway departure crashes. The Federal Highway Administration (FHWA) reports that shoulder and edge line rumble strips reduce single-vehicle run-off-the-road injury crashes by 10–24% on rural freeways and 26–46% on two-lane rural roads (FHWA 2011). In the area where the truck departed the roadway, 60-foot sections of rumble stripes were located along the edge line with 15-foot gaps to accommodate bicyclists, as required by TDOT. It is likely that the truck's right wheels would have encountered the rumble stripes when the truck departed the road; however, the truck's wheels would have been atop the edge line and the shoulder was only about 1 foot wide, leaving little time for the driver to react as the truck crossed the edge line and then redirect the truck before it dropped off the shoulder into the v-ditch.

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[46] Of the five locations where the pavement edge drop-off exceeded 1.75 inches, three were located where the service truck's right-most tire mark was on the foreslope and two were located where the service truck's right-most tire mark was on the pavement.

[47] For more information about rumble strips, see https://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/general-information.cfm (accessed July 28, 2022).

Lane departure warning (LDW) systems and lane-keeping assist (LKA) systems (sometimes called lane departure prevention [LDP] systems) are vehicle technologies designed to keep drivers from unintentionally departing from their travel lanes.[48] These systems use information from vehicle-based cameras to determine if a vehicle is about to move out of its lane. The truck involved in the Decatur crash was not equipped with either an LDW system or an LKA system, nor was it required to be.

In general, an LDW system alerts the driver when the vehicle begins to move or is about to move from its travel lane and relies on the driver to respond to the alert; it does not intervene to take corrective action. An LKA 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.

Overall, LDW and LKA systems have been found to be effective in reducing truck crashes (Camden and others 2017, Montiglio and others 2006, Roozendaal and others 2020). Camden and others concluded that LDW may prevent 13–53% of large-truck road departures, sideswipes, and head-on crashes. The ranges of effectiveness can be attributed, at least in part, to differences in system capabilities over time. Additionally, design features from one LDW or LKA system to another system can influence effectiveness (Roozendaal 2020). For example, the timing of the alerts vary; some issue an alert to the driver before crossing the lane marking whereas other systems may not issue an alert until the vehicle is on or over the lane marking. Some systems incorporate an audio alert, others use a haptic alert through the steering wheel and yet others alert the driver with a vibration in the seat. The LKA intervention may be steering or differential-braking. Additionally, the foundation of both LDW and LKA 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.

Currently, the United States has no requirements or performance standards for LDW or LKA systems for heavy vehicles. However, NHTSA provides test specifications for LDW systems in light vehicles with a GVWR up to 10,000 pounds for New Car Assessment Program purposes.[49] Further, section 24208 of the Infrastructure

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[48] For additional information about these systems, see NHTSA's webpage on Driver Assistance Technologies | NHTSA (accessed July 27, 2022).

[49] NHTSA's New Car Assessment Program provides comparative information about the safety performance of new vehicles to assist consumers with vehicle purchasing decisions and to encourage safety improvements. For more information, see Car Safety Ratings | Vehicles, Car Seats, Tires | NHTSA (accessed August 10, 2022). For more information about NHTSA's test specifications for LDW systems in light vehicles, see Lane Departure Warning System Confirmation Test and Lane Keep Support Performance Documentation, available at Regulations.gov (accessed August 10, 2022).

Investment and Jobs Act (Public Law 117-58, signed on November 15, 2021) calls for NHTSA to develop minimum performance standards for crash avoidance technology, including LKA systems, and to require that all passenger motor vehicles manufactured for sale in the United States be equipped with LDW and LKA systems, among other safety technologies.

Despite a lack of performance standards, heavy vehicle manufacturers are developing and offering LDW and LKA systems on their vehicles. In 2015, Daimler (Freightliner Trucks is a division of Daimler Trucks North America) introduced a suite of safety systems called Detroit Assurance. The current version (Detroit Assurance 5.0) is designed for Cascadia model truck-tractors and includes active lane assist.[50] Daimler does not offer collision mitigation technology as standard equipment for incomplete chassis builds, such as the truck involved in this crash, due to the numerous build configurations and weights that can result in the final vehicle product. However, the Bendix AutoVue® LDW system was an optional feature that could have been purchased for the Freightliner M2 incomplete chassis vehicle involved in this crash.[51] The NTSB is aware that other vehicle manufacturers such as Volvo Trucks of North America offers LKA systems on its trucks.[52] Furthermore, other systems are available such as the LKA system developed by Bosch and the Onlane LDW system produced by Wabco.[53]

In 2021, the NTSB issued Safety Recommendation H-21-1 to NHTSA to require all newly manufactured commercial vehicles with GVWRs above 10,000 pounds to be equipped with LDP systems.[54] This recommendation was issued as a result of the investigation of a single-vehicle crash in Bryce Canyon City, Utah, involving a medium-size bus that departed from the road, returned to the road, and rolled over

[50] For more information, see the Daimler brochure on Detroit Assurance® Suite of Safety Systems DETROIT ASSURANCE® 5.0 at: https://freightlineradsaem.azureedge.net/content/dam/enterprise/documents/3933-detroit_assurance_5.0_brochure-2019-05-08.pdf (accessed July 27, 2022).

[51] For more information about Bendix's AutoVue® Lane Departure Warning System, see https://www.bendix.com/en/products/autovue/AutoVue.jsp (accessed September 9, 2022).

[52] For more information about Volvo's dynamic steering system, see https://www.volvotrucks.com/en-en/news-stories/magazine-online/2018/aug/new-updated-vds.html (accessed July 26, 2022).

[53] For more information about Bosch's lane-keeping assist system, see https://www.bosch-mobility-solutions.com/en/solutions/assistance-systems/lane-keeping-assist-cv/ (accessed July 26, 2022). For more information about Wabco's lane departure warning system, see https://doc.wabco-auto.com/ProductFiles/anteros/Document/8150101973.pdf (accessed July 26, 2022).

[54] Because technology has advanced beyond warning systems to also incorporate lane-keeping technologies, Safety Recommendation H-21-1 superseded Safety Recommendation H-10-1, which asked NHTSA to require new commercial motor vehicles to be equipped with LDW systems.

(NTSB 2021). NHTSA responded on August 30, 2021, and reported that it is conducting research to evaluate how drivers perform when using heavy-vehicle LDP systems. Safety Recommendation H-21-1 was classified "Open—Acceptable Response" on May 2, 2022.

In this crash, the service truck departed the roadway at a shallow angle (about 1.5°) at an estimated speed of 52 mph, when the driver was reportedly looking in his side rear-vision mirrors. The lane lines near the road departure were in good condition. An LDW system would have notified the driver of an impending lane departure, alerting him to take action to prevent the departure; however, the space available to the truck driver for recovery was limited to a 1-foot shoulder, which may not have been sufficient for recovery. Had an LKA/LDP system been installed on the truck, it would have detected the lane markings on the road, warned the driver of the movement from the lane, and—if the driver did not respond—could have actively intervened to maintain lane positioning before the truck entered the shoulder. The NTSB concludes that an LDW system would have alerted the truck driver that the truck was leaving the lane, while an LKA system (also known as an LDP system) would have actively assisted the truck driver in keeping the truck within the travel lane, preventing the roadway departure. Therefore, the NTSB reiterates Safety Recommendation H-21-1 to NHTSA.

2.5 School Bus Safety

2.5.1 School Bus Crash Statistics and Type D School Buses

Fatal school-transportation-related events are rare and, during a 10-year period from 2011 to 2020, an average of 113 fatalities occurred per year (NHTSA 2022).[55] Most of these fatalities were occupants in the other vehicle (70%), not in the school transportation vehicle. For occupants in the school transportation vehicles, an average of five driver fatalities and six passenger fatalities occurred during the 10-year period.

The school bus involved in the Decatur crash was a Type D, transit-style or flat front bus. The entrance door is located forward of the front wheels and the engine is frequently located in the rear, but in some cases in the front (National Congress on School Transportation 2015). Type D buses make up about 10% of new school bus sales annually in the United States; in 2020, a total of 2,946 such buses entered the

[55] These findings are based on data from the Fatality Analysis Reporting System maintained by NHTSA. According to NHTSA, "a school-transportation-related crash is a motor vehicle traffic crash that directly or indirectly involves a school transportation vehicle. These vehicles include those of a school bus body type or a non-school-bus functioning as a school bus, transporting children to and from school or school-related activities."

market.[56] Type D school buses have some advantages, such as a broader front window that provides the driver with better visibility of students as they enter and exit the bus, better visibility during turning maneuvers, and a larger passenger seating capacity.[57] However, the flat front design inherently has less space before intrusion might occur into the driver compartment, especially in collisions with larger, higher vehicles.

The frontal crashworthiness of school buses has been studied over the years to determine the effectiveness of compartmentalization in preventing passenger injuries (NHTSA 2002, IMMI 2015). In the NHTSA study, a Type C school bus (the most common style) was crashed into a rigid barrier at 30 mph (48.3 km/h), which is similar to crash tests done for passenger vehicles (NHTSA 2002).[58] The large mass of a school bus makes a rigid barrier impact very severe at 30 mph. The Type C school bus sustained significant frontal damage in the crash test (see figure 14).

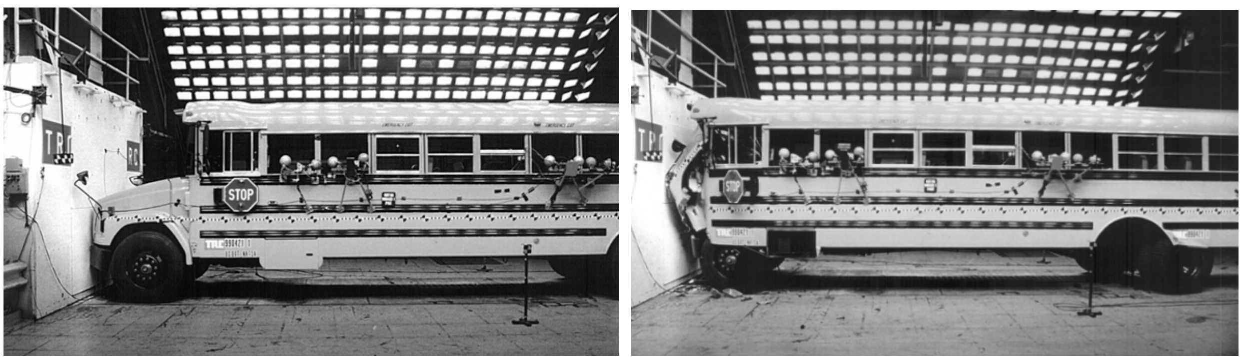

Figure 14. Pre and postcrash photographs of NHTSA's frontal crash test for school buses. (Source: NHTSA 2002)

The flat front design of the Type D school bus places the driver forward of the front wheels and in a position with little space for intrusion before injury may result. In most crashes, such as those between a school bus and a passenger vehicle, the height of the school bus driver's seating position is above the intrusion zone.

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[56] For more information, see North American Bus Sales 2020, at https://www.schoolbusfleet.com/management/10131913/north-american-school-bus-sales-2020 (accessed July 27, 2022).

[57] For more information about bus design, see (a) Front Engine vs Rear Engine Buses: What's Best for You, at https://www.nationalbus.com/blog/2021/04/13/front-engine-vs-rear-engine-buses-whats-best-for-you/ (accessed July 27, 2022), and (b) Transit Concept Why Buy a Transit Bus, at Why Buy a Blue Bird Transit Bus? Why Buy from Central States? - Central States Bus Sales (accessed October 25, 2022).

[58] (1) A *Type C* or conventional-style school bus has a GVWR of more than 10,000 pounds and is designed to carry more than 10 passengers. The engine is located in front of the windshield and the entrance door is behind the front wheels. (2) See FMVSS 208, "Occupant Crash Protection," at 49 *CFR* 571.208.

However, in crashes with other large vehicles, intrusion may occur at the bus driver's seating location.

The school bus in the Decatur crash sustained a frontal impact with the service truck at 46 mph, substantially higher than the speed in NHTSA's school bus crash test. The impact resulted in severe crushing of the entire front of the school bus and intrusion into the driver compartment and loading area. The crushed structure of the bus was slightly more pronounced on the left side due to the movement of the truck laterally in front of the bus from left to right. Upon impact, the bus experienced a rapid forward deceleration, evidenced by the damage to the bus and the short distance to its final rest location, and a left-to-right movement as it collided with the truck. Although the bus driver was restrained by a lap/shoulder belt, the intrusion from the impact resulted in a loss of survival space.[59] The NTSB concludes that the school bus driver's survival space was compromised during the impact into the side of the truck due to the severity of the collision.

School bus driver fatalities are rare events. The drivers are afforded protection during a collision by the school bus size, their seating position above most other vehicles, and their use of lap/shoulder belts. Additional protection is best achieved through technologies to prevent collisions in the first place, such as those that reduce crossover events (detailed in section 2.4).

2.5.2 Passenger Lap/Shoulder Belts on School Buses

The school bus involved in this crash was not equipped with passenger lap or lap/shoulder belts nor was it required to be equipped with belt systems. Instead, school buses with a GVWR greater than 10,000 pounds are required to be designed with a passive form of occupant protection called "compartmentalization," which requires no action by the passenger and functions by forming a compartment in front of and behind the bus occupant.[60] It is designed to contain passengers within their seating compartments during frontal and rear impact collisions. A key aspect of this occupant protection system is that passengers remain within the compartment before and during an impact so that they benefit from the energy-absorbing design of the seats. Properly worn passenger lap/shoulder belts enhance compartmentalization by restraining the upper body and pelvis within the seating compartment during all crash scenarios, thus allowing the passenger to benefit from the protection of the strong bus body and the compartmentalized seating system, and therefore be able to

[59] *Survival space* is the interior portion of a vehicle that maintains livable space during a crash.

[60] Compartmentalization is regulated by FMVSS 222, "School Bus Passenger Seating and Crash Protection," 49 *CFR* 571.222.

"ride down" the crash event.[61] The NTSB has shown that a properly worn lap/shoulder belt provides a higher level of protection than compartmentalization alone, particularly in rollover or side impact crashes with severe lateral motion (NTSB 2018, NTSB 2016).

Compartmentalization is designed to protect properly seated passengers in frontal impacts such as this one. Evaluation of the video evidence determined that three of the seriously injured students were out of position immediately before the crash; that is, the student in seat 1C was kneeling on the seat and facing aft, the student in seat 1F was either kneeling or standing and facing aft, and the student in seat 3C was turned toward the aisle. The other visible students in row 3 were seated facing forward, in a position to maximize the benefits of compartmentalization, and as a result were less injured during the crash sequence. Additionally, 11 of the 23 passengers aft of row 3 were seated in what would also be considered out-of-position seating positions, yet none suffered serious injury, most likely because of their greater distance from the impact location. Passengers who are out of position and outside the seating compartment, such as those standing or even leaning toward or across the aisle, are not afforded the advantage of the seat compartmentalization and are exposed to a higher risk of injury from crash forces, particularly when closer to the impact area. The NTSB concludes that out-of-position seating positions for those students closer to the area of impact increased their injury level.

Properly worn lap/shoulder belts could have lessened the severity of the passengers' injuries. The video showed that when the bus decelerated, the passengers were thrown forward in the compartment. The out-of-position passengers would be especially at risk of being thrown from their seating compartment, impacting seat structures, other interior furnishings, or other occupants, and they would not benefit from the energy-absorbing design of the seats. The passenger in seat 1F who was seriously injured was facing aft, standing or kneeling with his upper body above the partition. This position would have placed him at high risk for being thrown over the partition and toward the intrusion area. Had the passenger been sitting properly in his seat, a lap/shoulder belt would have kept him away from the intrusion area.[62] The fatally injured passenger, who was seated behind the driver with her head and shoulder against the bus's sidewall and not out of position, was displaced forward between the sidewall and the partition. A lap/shoulder belt would

[61] A *ride-down* effect brings the bus passenger to a stop with the vehicle, rather than having the passenger continue to move and strike the interior parts of the bus.

[62] As noted in section 1.4.2, the restraining barrier (partition) on the loading side of the school bus may not have been in compliance with FMVSS 222, paragraph S5.2.3. The injuries sustained by the student in seat 1F are consistent with injuries from sharp edges associated with the intrusion zone, as opposed to blunt and padded surfaces in the seating area. Investigators cannot determine how the injuries sustained by the passenger in seat 1F would have been affected by a noncompliant versus a compliant barrier.

have limited her movement and retained her in the seat, keeping her farther away from the impact area. As stated in the probable cause from a 2014 Anaheim, California, NTSB crash investigation, the severity of passenger injuries in the area of maximum intrusion can be reduced with the proper use of the available lap/shoulder belts by the student passengers seated in this area (NTSB 2016).

Proper use of passenger lap/shoulder belts restrains the pelvis and upper torso and ensures that the occupant is seated within the seating compartment throughout a crash sequence, providing benefits of both the restraint system and compartmentalization to protect the occupant from crash forces. In this crash, had the students who suffered fatal and serious injuries been restrained with lap/shoulder belts, they would have remained in their seats, their forward movement toward the impact and intrusion area would have been limited, and thus their risk of injury would have been reduced. The NTSB concludes that the use of lap/shoulder belts would have lessened the forward inertial movement of passengers during the deceleration due to vehicle braking and impact, thereby reducing the risk of injury, especially for those passengers near the impact area.

As part of a special investigation report on school bus transportation (NTSB 2018), the NTSB issued Safety Recommendation H-18-10 to states without requirements for seat belts on school buses, including Tennessee, to enact legislation to require that all new large school buses be equipped with passenger lap/shoulder belts for all passenger seating positions in accordance with FMVSS 222, "School Bus Passenger Seating and Crash Protection" (49 *CFR* 571.222).[63] Recognizing that Florida, Louisiana, New Jersey, and New York already required lap belts on school buses, the NTSB asked in Safety Recommendation H-18-9 that these states amend their statutes to upgrade the seat belt requirement from lap belts to lap/shoulder belts for all passenger seating positions in new large school buses in accordance with FMVSS 222.[64] Since issuing these recommendations, only two additional states (Iowa and New Jersey) have enacted legislation to require lap/shoulder belts for all passenger seating positions in new large school buses.

[63] Safety Recommendation H-18-10 is classified "Closed—Acceptable Action" for Iowa; "Open—Acceptable Response" for Arizona, Connecticut, Hawaii, Illinois, Indiana, Kansas, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Mexico, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Utah, Virginia, Washington, and West Virginia; and "Open—Unacceptable Response" for Alabama, Alaska, Colorado, Delaware, District of Columbia, Georgia, Idaho, Kentucky, Maine, Maryland, North Carolina, North Dakota, Puerto Rico, South Dakota, Vermont, Wisconsin, and Wyoming.

[64] Safety Recommendation H-18-9 is classified "Closed—Acceptable Action" for New Jersey, "Open—Acceptable Response" for New York, and "Open—Unacceptable Response" for Florida and Louisiana.

Safety Recommendation H-18-10 was classified "Open—Acceptable Response" for the state of Tennessee pending the Tennessee General Assembly revising the state's law to require lap/shoulder belts on new school buses on February 1, 2021. In 2018, Tennessee considered legislation requiring seat belts on newly purchased school buses but it failed to pass.[65] However, in 2018, Tennessee established a $3 million grant program to reimburse school districts for the additional costs associated with adding lap/shoulder belts to newly purchased buses or retrofitting qualifying buses already in operation. As of FY2020–2021, almost $827,000 had been awarded to school districts (Tennessee Department of Education 2022). At the federal level, the School Bus Safety Act of 2021 has been introduced in Congress and, if enacted into law, would direct the US DOT to require school buses with a GVWR greater than 10,000 pounds to be equipped with lap/shoulder belts and to establish a grant program to assist local educational agencies to purchase school buses with passenger lap/shoulder belts.[66]

Because the use of lap/shoulder belts would have reduced the risk of injury in the Decatur crash, the NTSB reiterates Safety Recommendation H-18-10 to the states, commonwealths, and the District of Columbia that do not currently require lap/shoulder belts on new school buses and reiterates Safety Recommendation H-18-9 to Florida, Louisiana, and New York.

2.5.3 Video Recordings on School Buses

The school bus was equipped with an inward-facing camera that captured student behavior during the ride before the crash. As already discussed, the video showed several students who were seated out-of-position (a few were kneeling or standing), which is unsafe because, in the event of a front or rear crash, they do not receive the benefits of compartmentalization. Onboard cameras can be used for monitoring driver and passenger behavior.

In 2010, in its investigation of a truck-tractor semitrailer rear-end collision into passenger vehicles on interstate 44 near Miami, Oklahoma, the NTSB issued Safety

[65] HB 395 was introduced to the Tennessee General Assembly by Tennessee State Representative JoAnne Favors, and SB 381 was introduced by Tennessee State Senator Todd Gardenhire. https://wapp.capitol.tn.gov/apps/billsearch/billsearchadvancedarchive.aspx?terms=school+bus&searchtype=all&ga=110.

[66] (a) H.R. 3381 was introduced in the US Congress on May 20, 2021, by US Representative Steve Cohen (Tennessee). An identical bill, S. 2539, was introduced in the US Senate on July 29, 2021, by US Senator Tammy Duckworth (Illinois). (b) The Act endorses several other safety features identified in NTSB recommendations related to school buses, to include: a fire suppression system that addresses engine fires, a firewall that prohibits hazardous quantities of gas or flames to pass through the firewall from the engine compartment to the passenger compartment, an automatic emergency braking system, an event data recorder, and an electronic stability control system.

Recommendation H-10-10, asking the FMSCA to require all heavy commercial vehicles to be equipped with video event recorders that capture data in connection with the driver and with the outside environment and roadway in the event of a crash or sudden deceleration event (NTSB 2010). This requirement would apply to school buses. In June 2019, the NTSB classified Safety Recommendation H-10-10 "Closed—Unacceptable Action," because the FMCSA did not implement the requirement. The FMCSA stated that the administration had removed the barriers to installing onboard video recorders but did not want to mandate installation, instead focusing on a voluntary installation process.

Specific to school buses, the NTSB discussed the benefits of onboard video recording systems in its investigation of a 2013 school bus crash in Port Saint Lucie, Florida, in the 2015 report *Commercial Vehicle Onboard Video Systems* (NTSB 2015).[67] In the report, the NTSB highlighted that video recordings can be used to better understand the vehicle and passenger dynamics during a crash as well as be used as a tool to enforce rules, such as seat belt use. The NTSB issued Safety Recommendation H-15-2 to the American Bus Association, the United Motorcoach Association, the American Trucking Associations, the National Association for Pupil Transportation, the National Association of State Directors of Pupil Transportation Services, and the National School Transportation Association, asking these organizations to encourage their members to ensure that any onboard video system in their vehicles provides visibility of the driver and of each occupant seating location, visibility forward of the vehicle, optimized frame rate, and low-light recording capability (Safety Recommendation H-15-12). That recommendation is classified "Closed—Acceptable Action" for the school bus organizations because they promoted the recommendation through news articles, letters to members, and presentations.[68] Furthermore, the NTSB's recommendation was adopted by delegates to the 2015 National Congress on School Transportation and language was added to the National School Transportation Specifications and Procedures document, which serves as the primary guidance for school bus vehicle specifications and operational procedures in the United States.

Recently, based on investigating a multivehicle crash on the Pennsylvania Turnpike near Mt. Pleasant Township, Pennsylvania (NTSB 2022), the NTSB again called for the installation of onboard video recording devices and issued Safety Recommendation H-22-3 to NHTSA:

[67] A 2011 motorcoach crash in Kearney, Nebraska, was also included in the report.

[68] Safety Recommendation H-15-2 is also classified "Closed—Acceptable Action" for the American Trucking Associations. It was reiterated to the American Bus Association and the United Motorcoach Association on March 9, 2022, in connection with the Mt. Pleasant Township crash investigation. The recommendation is classified "Open—Await Response" for both organizations.

> Require that all buses and trucks over 10,000 pounds gross vehicle weight rating be equipped with onboard video event recorders that record, at a minimum, parametric data associated with the event, such as real clock time, GPS location, and acceleration data, and visibility of the driver's face and of each occupant seating location, visibility of the instrument panel, visibility forward of the vehicle, optimized frame rate, and low-light recording capability.

NHTSA responded on June 7, 2022, stating that it is continuing research on driver monitoring. The response is currently under review by the NTSB.

Recorded information can provide valuable information for evaluating the circumstances leading to a crash, as well as critical vehicle dynamics and occupant kinematics data for assessing crash severity. In this case and as described in section 1.9.1, the inward-facing camera video footage on the school bus was used to identify the seating locations and movement of the passengers before impact. The simultaneous displacement of the students provided valuable information about the school bus driver reacting to the truck and applying the brakes before impact. The NTSB concludes that the inward-facing cameras on the school bus provided critical occupant kinematics data used in the Decatur crash investigation. Therefore, the NTSB reiterates Safety Recommendation H-22-3 to NHTSA.

Although not required, school systems install onboard video recorders for multiple purposes, including driver and passenger monitoring. Before the crash, the Meigs County School District had been reviewing video footage for use with driver evaluations and identifying areas for driver improvement. Since the crash, more emphasis has been placed on examining student seating behavior during the video review. When students are observed to be seated out of position on school buses, that information could be used to engage in conversations with drivers, students, and parents about the importance to be properly seated in the seating compartment and to use restraints when available.

Onboard camera recordings can be used proactively to aid in driver, student, and parent training to ensure that students on school buses sit properly, use seat belts, and exhibit other safe behaviors. The benefits of compartmentalization and lap/shoulder belts will only be realized if students are seated properly and lap/shoulder belts are properly worn. The NTSB concludes that reviewing onboard video event recorder information can help operators identify risky student behaviors, such as out-of-position seating positions or improper use of available lap/shoulder belts; such reviews can then be used as a basis to train students on proper seating and lap/shoulder belt usage. Therefore, the NTSB recommends that the National Association for Pupil Transportation, the National Association of State Directors of Pupil Transportation Services, and the National School Transportation Association inform their members of the need to periodically review onboard video event recorder information to ensure that students engage in safe transportation behaviors on school buses, including sitting properly and wearing seat belts, when available, and that the members use this information to improve the bus safety training provided to drivers, students, and parents.

3. Conclusions

3.1 Findings

1. None of the following were factors in this crash: (1) mechanical condition of the service truck or school bus; (2) management safety practices of Service Electric Company and Meigs County School District; (3) service truck and school bus driver licensing, training, and experience; (4) alcohol and other potentially impairing drug use; (5) the service truck driver's cell phone use or schedule; or (6) weather.

2. The emergency response to the crash was timely and effective.

3. No available evidence suggests that the truck driver's diabetes or obstructive sleep apnea contributed to the crash.

4. The truck driver failed to keep his vehicle on the roadway due to his inattention to the forward roadway when he was looking at the sheriff's deputy vehicle behind him.

5. In response to unintentionally driving off the roadway, the truck driver steered the truck toward the left; as the truck's right front wheel returned to the roadway the truck yawed counterclockwise.

6. Although the school bus driver had time to react to the truck crossing into her travel lane, she did not have enough time to avoid the collision.

7. The school bus driver reacted quickly by braking when the service truck crossed over into the bus's travel lane; therefore, factors such as her medical conditions, her use of medications, and the potential for fatigue or distraction likely did not contribute to the crash or its severity.

8. The truck driver's ability to safely return to the roadway was affected negatively by the non-recoverable and critical foreslopes of the earthen v-ditch and the height of the pavement edge drop-off, which contributed to the vehicle yawing as it returned to the roadway.

9. The Tennessee Department of Transportation improvement project to reshape and flatten the foreslopes of the earthen v-ditch and to eliminate the pavement edge drop-off will provide drivers who leave the roadway a better opportunity to regain control of their vehicle.

10. A lane departure warning system would have alerted the truck driver that the truck was leaving the lane, while a lane-keeping assist system (also

known as a lane departure prevention system) would have actively assisted the truck driver in keeping the truck within the travel lane, preventing the roadway departure.

11. The school bus driver's survival space was compromised during the impact into the side of the truck due to the severity of the collision.

12. Out-of-position seating positions for those students closer to the area of impact increased their injury level.

13. The use of lap/shoulder belts would have lessened the forward inertial movement of passengers during the deceleration due to vehicle braking and impact, thereby reducing the risk of injury, especially for those passengers near the impact area.

14. The inward-facing cameras on the school bus provided critical occupant kinematics data used in the Decatur crash investigation.

15. Reviewing onboard video event recorder information can help operators identify risky student behaviors, such as out-of-position seating positions or improper use of available lap/shoulder belts; such reviews can then be used as a basis to train students on proper seating and lap/shoulder belt usage.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Decatur, Tennessee, crash was the service truck driver's inattention to the forward roadway due to his looking at a sheriff's vehicle behind him, which resulted in his failure to keep the truck on the roadway. Contributing to the cause of the crash were non-recoverable and critical foreslopes and the pavement edge drop-off along the state highway, which prevented the truck driver from safely returning the truck to the roadway in a controlled manner. Contributing to the severity of the crash was the lack of passenger lap/shoulder belts on the school bus and the unsafe seating positions by some of the students.

4. Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendation:

To the National Association for Pupil Transportation, the National Association of State Directors of Pupil Transportation Services, and the National School Transportation Association:

> Inform your members of the need to periodically review onboard video event recorder information to ensure that students engage in safe transportation behaviors on school buses, including sitting properly and wearing seat belts, when available, and that the members use this information to improve the bus safety training provided to drivers, students, and parents. (H-22-25)

4.2 Previously Issued Recommendations Reiterated in This Report

The National Transportation Safety Board reiterates the following 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)

> Require that all buses and trucks over 10,000 pounds gross vehicle weight rating be equipped with onboard video event recorders that record, at a minimum, parametric data associated with the event, such as real clock time, GPS location, and acceleration data, and visibility of the driver's face and of each occupant seating location, visibility of the instrument panel, visibility forward of the vehicle, optimized frame rate, and low-light recording capability. (H-22-3)

To the States of Florida, Louisiana, and New York:

> Amend your statutes to upgrade the seat belt requirement from lap belts to lap/shoulder belts for all passenger seating positions in new large school buses in accordance with Federal Motor Vehicle Safety Standard 222. (H-18-9)

To the States of Alabama, Alaska, Arizona, Colorado, Connecticut, Delaware, Georgia, Hawaii, Idaho, Illinois, Indiana, Kansas, Maine, Maryland, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Vermont, Washington, West Virginia, Wisconsin, and Wyoming; the Commonwealths of Kentucky, Massachusetts, Pennsylvania, Puerto Rico, and Virginia; and the District of Columbia:

> Enact legislation to require that all new large school buses be equipped with passenger lap/shoulder belts for all passenger seating positions in accordance with Federal Motor Vehicle Safety Standard 222. (H-18-10)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

MICHAEL GRAHAM
Member

BRUCE LANDSBERG
Vice Chairman

THOMAS CHAPMAN
Member

Report Date: October 18, 2022

Appendixes

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of the Decatur, Tennessee, crash on October 27, 2020, and dispatched a partial investigative team (after Covid-related travel restrictions were lowered in that region), consisting of the investigator-in-charge and the vehicle factors investigator. 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, the Tennessee Highway Patrol, the Tennessee Department of Transportation, and the Meigs County School District.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* 1117(b) requires the following information on the recommendations in this report.

For each recommendation–

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

(2) a description of the Board'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 Association for Pupil Transportation, the National Association of State Directors of Pupil Transportation Services, and the National School Transportation Association:

H-22-25

Inform your members of the need to periodically review onboard video event recorder information to ensure that students engage in safe transportation behaviors on school buses, including sitting properly and wearing seat belts, when available, and that the members use this information to improve the bus safety training provided to drivers, students, and parents.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in sections 1.9.1 Video Study and 2.5.3 Video Recordings on School Buses. Information supporting (b)(1) can be found on pages 25 and 43–46; (b)(2) can be found on pages 43–46; and (b)(3) is not applicable.

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