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Multivehicle Crash Near Mt. Pleasant Township, Pennsylvania

January 5, 2020

About 3:30 a.m. on January 5, 2020, on the westbound Pennsylvania Turnpike near Mt. Pleasant Township, Pennsylvania, a motorcoach carrying 59 passengers ran off the right side of the road, hit the adjacent embankment, and overturned, blocking all westbound lanes. The motorcoach was rounding a curve at night and in light snow. Within seconds, two trucks towing semitrailers that were following the motorcoach hit it. A westbound car and a third truck drove off the road to avoid the wreckage. The motorcoach driver, two passengers, and both occupants of the second truck died in the crash; 49 of the motorcoach passengers and the codriver of the first truck were injured. The driver of the first truck, the occupants of the third truck, and the occupants of the car were uninjured.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ABS	antilock braking system
AEB	automatic emergency braking
ARA	Applied Research Associates
BASICs	Behavior Analysis and Safety Improvement Categories
BMI	body mass index
CAMP	Crash Avoidance Metrics Partnership
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
DDEC	Detroit Diesel Electronic Control
DOT	US Department of Transportation
DSRC	dedicated short-range communication
DVIR	driver vehicle inspection report
ECM	engine control module
ELD	electronic logging device
EMS	emergency medical service
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FedEx	FedEx (formerly Federal Express) Ground Package System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSRs	*Federal Motor Carrier Safety Regulations*
FMVSS	Federal Motor Vehicle Safety Standard
g	gravitational acceleration
gm/dL	grams per deciliter
GNSS	global navigation satellite system
GPS	global positioning system
GVWR	gross vehicle weight rating

hp	horsepower
kg/m^2	kilograms per square meter
IIHS	Insurance Institute for Highway Safety
MDMA	methylenedioxymethamphetamine (Ecstasy or Molly)
NCHRP 966	National Cooperative Highway Research Program 966
NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
PCP	phencyclidine
PennDOT	Pennsylvania Department of Transportation
Penske	Penske Truck Leasing, Inc.
psi	pound-force per square inch
sUAS	small unmanned aircraft system
THC	tetrahydrocannabinol (cannabis)
TTU	tractor telemetry unit
UPS	United Parcel Service of America
USC	*United States Code*
V2V	vehicle-to-vehicle
V2X	vehicle-to-everything

Executive Summary

What Happened

About 3:30 a.m. on January 5, 2020, on the westbound Pennsylvania Turnpike near Mt. Pleasant Township, Pennsylvania, a motorcoach carrying 59 passengers ran off the right side of the road, hit the adjacent embankment, and overturned, blocking all westbound lanes. The motorcoach was rounding a curve at night and in light snow. Within seconds, two trucks towing semitrailers that were following the motorcoach hit it. A westbound car and a third truck drove off the road to avoid the wreckage. The motorcoach driver, two passengers, and both occupants of the second truck died in the crash; 49 of the motorcoach passengers and the codriver of the first truck were injured. The driver of the first truck, the occupants of the third truck, and the occupants of the car were uninjured.

What We Found

The regulatory speed limit on the turnpike is 70 mph, with an advisory speed of 55 mph on the curve where the crash occurred. The motorcoach driver entered the curve at 77 mph and struck the embankment at a speed of about 60 mph before overturning. We found that the motorcoach's engine brake was likely engaged, which can decrease traction on wet roadways. The first truck hit the motorcoach at a speed of about 21 mph, causing minor damage. The second truck crashed into the first truck and the motorcoach, causing catastrophic damage; its last recorded speed was 56 mph.

Most states use guidance from the Federal Highway Administration (FHWA) for setting speed limits, yet some of this guidance is outdated and should be de-emphasized. One method to help drivers reduce their vehicle's speed is variable speed limit signs that change the regulatory speed limit and are enforceable, such as by speed safety cameras, which are an effective countermeasure to reduce speeding-related crashes. In this crash, we found that such signs could have led the drivers to travel at lower speeds and potentially prevented or mitigated the crash. Another method for reducing vehicle speeds is advanced speed-limiting technology in vehicles, which could also help drivers avoid exceeding speed limits.

We determined that the circumstances of the impacts for each of the three trucks were likely outside the capabilities of the collision avoidance system available on the vehicles or outside the testing performance protocols being developed by the National Highway Traffic Safety Administration (NHTSA). However, it is critical that the full functionality of installed collision avoidance systems be maintained in the event they are necessary. In this crash, we found that one of the truck's collision avoidance systems was not operational and that commercial drivers could improve vehicle safety by reporting defects or faults in collision avoidance systems on driver vehicle inspection report forms.

We also found that connected vehicle technology, if installed on the vehicles involved in the crash, could have provided information about the overturned motorcoach in the roadway to alert drivers to the hazard they were approaching. However, recent regulatory action by the Federal Communications Commission (FCC) has reduced the size of the intelligent transportation system communication spectrum, allowing harmful interference from unlicensed devices, such as those that use wi-fi; we believe this action threatens the future deployment of connected vehicle technology.

Lastly, we found that video event recorder systems on commercial vehicles, such as that installed on one of the trucks, can provide vital information for evaluating the circumstances leading to a crash, as well as critical vehicle dynamics and occupant kinematics data for assessing crash severity. Further, motor carriers can proactively use the systems to aid in driver training and address driver behaviors that increase crash risk.

We determined that the probable cause of the crash near Mt. Pleasant Township, Pennsylvania, was the motorcoach driver's loss of control due to the motorcoach's unsafe speed on the wet curve and the driver's likely excessive steering inputs, which caused the motorcoach to run off the road, strike an embankment, and subsequently roll over across the roadway, which led to two commercial trucks colliding with the motorcoach. Contributing to the severity of the crash was the high initial and impact speed of the second truck.

What We Recommended

Because of the outdated nature of relying on the 85th percentile speed for determining speed limits, we recommended that the FHWA evaluate the applicability and use of the 85th percentile speed input variable in its tools for setting appropriate speed limits. To address speed on the Pennsylvania Turnpike, we recommended that the Commonwealth of Pennsylvania seek authority to allow speed safety cameras to be used on the turnpike outside of active work zones. We also recommended that the Pennsylvania Turnpike Commission implement the use of variable speed limit signs or other similar technology to adjust statutory speeds based on real-time information regarding weather and road conditions. Further, we reiterated a recommendation to the Commonwealth of Pennsylvania to authorize state and local agencies to use automated speed enforcement.

To address the importance of connected vehicle technology, we made recommendations regarding spectrum allocation and performance standards. We recommended that the US Department of Transportation implement a plan for nationwide connected vehicle technology deployment to address the limitations associated with the reduced spectrum for intelligent transportation systems and interference from unauthorized devices, such as those that use wi-fi. We also recommended that the FCC implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference from unlicensed devices, such as those that use wi-fi. We reiterated recommendations to NHTSA to develop minimum performance standards for connected vehicle technology for all highway vehicles and, once standards are developed, to require this technology to be installed on all newly manufactured highway vehicles.

We also reiterated recommendations to NHTSA to develop performance standards for advanced speed-limiting technology for heavy vehicles and, once standards are developed, to require that all newly manufactured heavy vehicles be equipped with such devices. Similarly, we also reiterated a recommendation to NHTSA to complete the development and application of performance standards for forward collision avoidance systems in commercial vehicles.

Regarding onboard video event recorders, we recommended that NHTSA require that all buses and trucks over 10,000 pounds gross vehicle weight rating be so equipped and that the Federal Motor Carrier Safety Administration (FMCSA) provide guidance to motor carriers to proactively use the onboard video event recorder information to aid in driver training and ensure driver compliance with regulatory rules essential for safe operation. We also reiterated a recommendation to the American Bus Association and the United Motorcoach Association 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.

Because of the importance that collision avoidance systems be operational, we recommended that the FMCSA add collision avoidance systems to the parts and accessories that the driver vehicle inspection report form will cover. We also recommended that the American Trucking Associations, the Owner-Operator Independent Drivers Association, the Commercial Vehicle Safety Alliance, the American Bus Association, and United Motorcoach Association, the Transport Workers Union of America, the Amalgamated Transit Union, and the International Brotherhood of Teamsters inform their members about the importance of drivers reporting faults concerning advanced safety features on the driver vehicle inspection report form (if they are not already identified on the form). We further recommended that the American Bus Association and the United Motorcoach Association inform their members about this crash and the need to incorporate FMCSA guidance into their training. Finally, we recommended that FedEx Ground Package System (FedEx) and United Parcel Service of America (UPS) require their drivers to report faults concerning advanced safety features, such as automatic emergency braking, in the optional section of the driver vehicle inspection report form (if they are not already identified on the form).

1. Factual Information

1.1 Crash Narrative

On Sunday, January 5, 2020, about 3:30 a.m., a multivehicle crash occurred in the westbound lanes of Interstate 70/76, also known as the Pennsylvania Turnpike, near the township of Mt. Pleasant in Westmoreland County, Pennsylvania (see figure 1). The crash site was in a curving, mountainous section of the turnpike 36 miles southeast of Pittsburgh, near milepost 86.1. Five vehicles were involved in the crash—a 2005 Van Hool 57-passenger motorcoach operated by Z&D Tour, Inc., of Rockaway, New Jersey; three 2018 Freightliner trucks (combination vehicles consisting of truck-tractors towing semitrailers), one operated by FedEx Ground Package System (FedEx) and two by United Parcel Service of America (UPS); and a 2007 Mercedes-Benz car.[1]

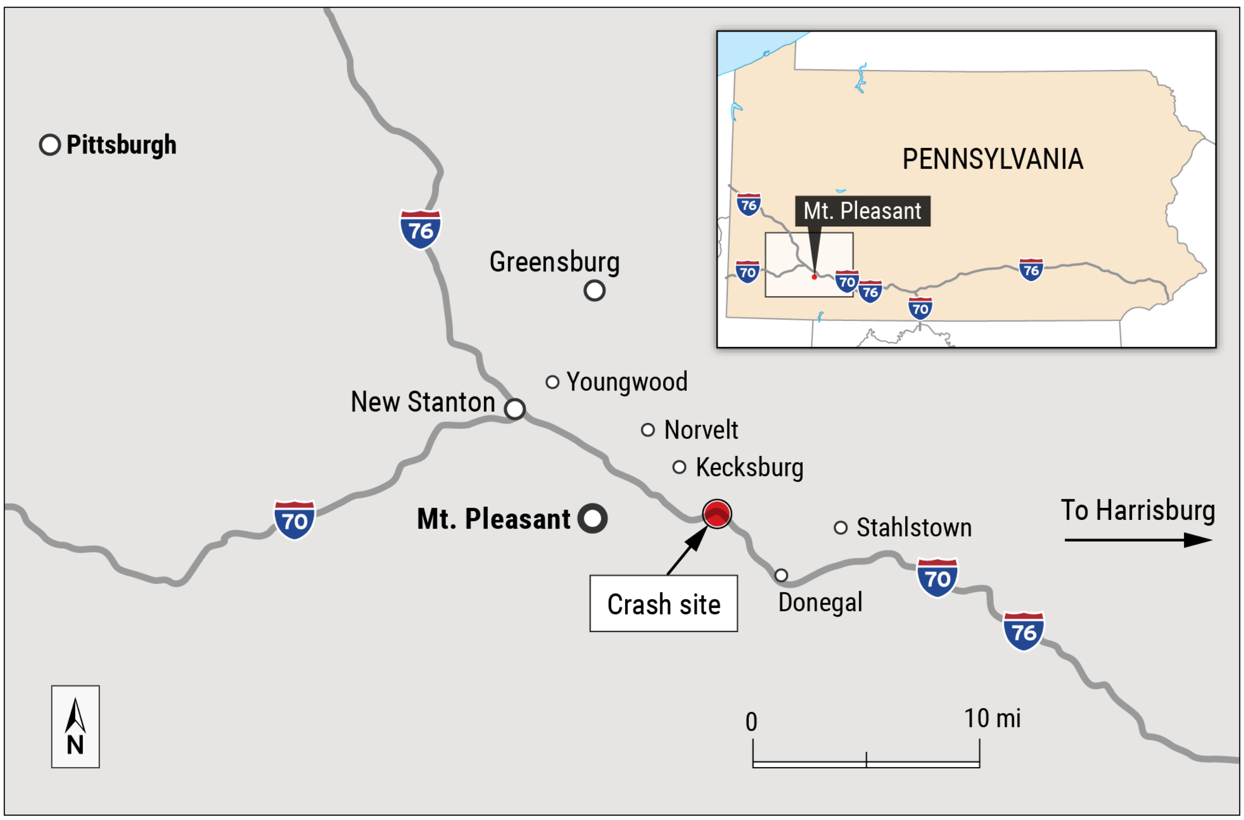

Figure 1. Map showing crash site and other locations mentioned in report.

[1] Visit ntsb.gov to find additional information in the public docket for this National Transportation Safety Board (NTSB) accident investigation (case number HWY20MH002). Use the CAROL Query to search safety recommendations and investigations.

The posted regulatory speed limit for the Pennsylvania Turnpike was 70 mph. Advisory speed signs of 55 mph were posted along the turnpike, recommending that motorists reduce their speed before entering the roadway's curves.[2] An advisory speed sign was posted on the right side of the westbound lanes about 2,112 feet in advance of the curve where the crash occurred (see figure 2). Electronic data, including recorded speed, were retrieved from the motorcoach, the FedEx truck, and the two UPS trucks. The data indicate that the drivers of all three trucks braked before the impacts.

Figure 2. Advisory 55-mph speed sign posted in westbound lanes approaching crash site.

The crash sequence began when the motorcoach, en route from New York City, New York, to Cincinnati, Ohio, departed the travel lanes, hit an embankment on the right side of the road, overturned, and blocked both westbound lanes of the turnpike. The motorcoach was occupied by a 58-year-old driver and 59 passengers,

[2] In contrast to regulatory speed signs, which are established by law, advisory speed signs are not enforceable. See section 1.7 for further information.

ranging in age from 4 to 59 years.[3] It had left New York about 10:00 p.m. on January 4 and made a rest and refueling stop about 15 minutes before the crash, according to passengers interviewed afterward. The motorcoach was due to arrive between 3:45 a.m. and 4:15 a.m. in New Stanton, Pennsylvania (10 miles from the crash site), where a relief driver would take over and continue to Cincinnati.

Light snow had been falling for several hours, and the temperature was below freezing. A maintenance crew from the Pennsylvania Turnpike Commission had been treating the road with salt since midnight, with the last treatment run occurring 10 minutes before the crash. The maintenance crew drivers reported seeing no ice on the road. Two of the truck drivers reported that the road was wet but not icy.

Just over a minute (71.2 seconds) before it overturned, the motorcoach passed the FedEx truck, as recorded by a forward-facing video camera mounted inside the truck's windshield.[4] Snow is seen falling on the video recording, with the road appearing wet but not snow covered. The motorcoach approached the left curve where the crash occurred at a recorded speed of 77 mph. While descending the curve's 3-percent slope, the motorcoach veered from the travel lanes across the right shoulder (equipped with grooved rumble strips), hit the adjacent earthen embankment, rolled 90° onto its right side, and slid to a stop on the roadway.[5] In the process, the motorcoach dislodged part of the concrete barrier in the median between the eastbound and westbound lanes. At final rest, the motorcoach straddled both westbound lanes and shoulders, with its undercarriage facing oncoming traffic (see figure 3). The roadway was not illuminated by highway lights near the crash location.

[3] The motorcoach was designed for 57 passengers. The NTSB has no information about the two extra passengers, such as where they were seated.

[4] The FedEx truck was equipped with two Lytx DriveCam video cameras, one facing forward and one facing inward, both mounted on the windshield.

[5] It is unclear which lane the motorcoach was traveling in before it left the road. See section 1.8 for details about the crash events and the data related to them.

Figure 3. Image from FedEx video showing motorcoach lying across roadway.

Shortly after the motorcoach came to rest across the highway, the FedEx truck collided with it. The truck, occupied by a 35-year-old male driver and a 35-year-old male codriver, was traveling in the right lane. It had entered the curve at 53 mph. As recorded by the truck's inward-facing camera and as stated in his interview with the NTSB, the driver maneuvered left in an attempt to avoid the motorcoach wreckage (see further discussion about inward-facing vehicle cameras in section 2.5). He said that the motorcoach looked like "a black wall." The FedEx truck crashed into the motorcoach at a speed of about 21 mph and came to rest blocking the left lane and median shoulder.

About 2 seconds later, the first UPS truck (UPS-1), traveling in the left lane, struck both the semitrailer of the FedEx truck and the overturned motorcoach. UPS-1 was occupied by a 53-year-old male driver and a 48-year-old male codriver. UPS-1 entered the curve at a speed of 71 mph. Its last recorded speed before the impact was 56 mph.[6]

A car occupied by a 46-year-old male driver and two 20-year-old male passengers was traveling in the right lane. Based on the evidence at the crash scene,

[6] As described in section 1.8.3, the recorded speed data for UPS-2 show a sudden drop from 67 mph to 0 mph, but it could not be determined how fast the truck was traveling when it struck the car.

the driver steered right to avoid the collision, crossed the right shoulder, and rode onto the embankment.[7] The car then came to a stop next to the right side of UPS-1.

The second UPS truck (UPS-2), which was also traveling in the right lane, entered the curve at 69 mph. UPS-2 was occupied by a 62-year-old male driver and a 41-year-old male codriver. The driver swerved right to avoid the other vehicles. The truck then crossed over the right shoulder and ran off the road, traveled partway up the embankment, hit the car, and came to rest between the embankment and the car. Figure 4 shows the final rest positions of all five vehicles.

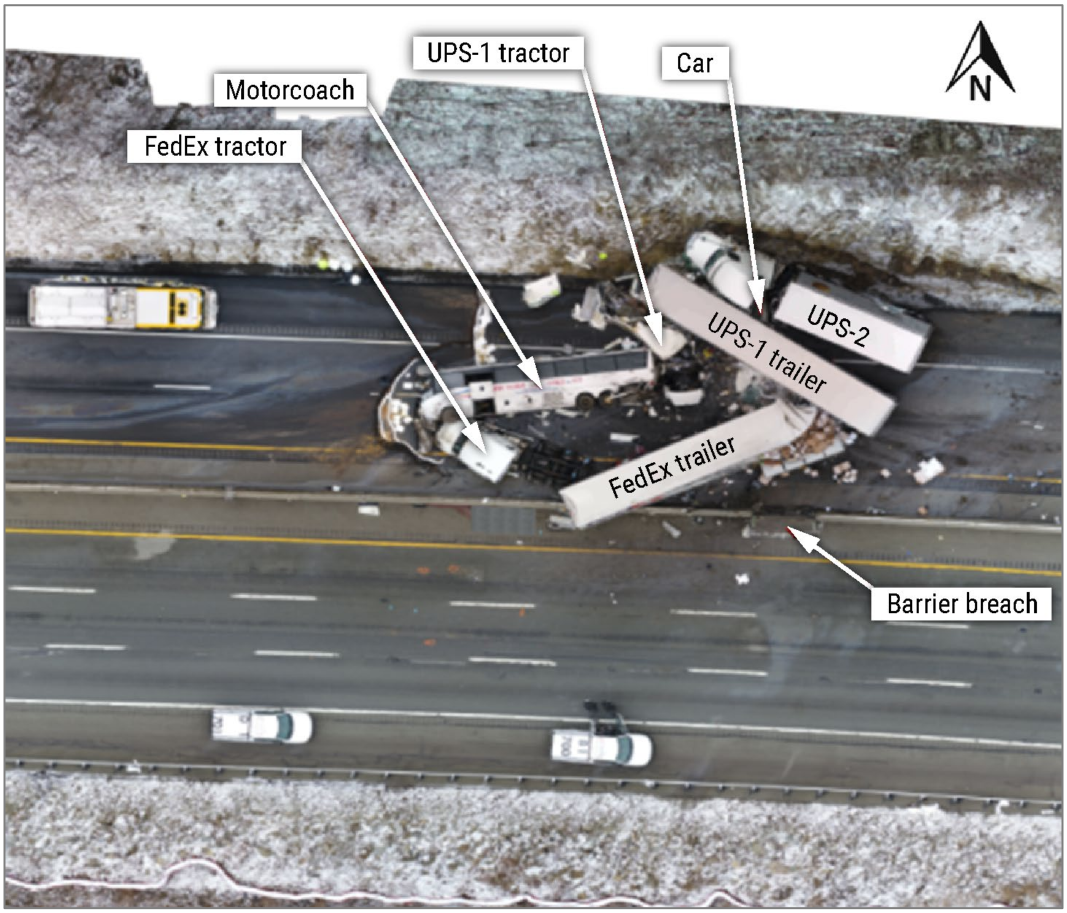

Figure 4. Final rest positions of all vehicles involved in crash. (Source: Pennsylvania State Police image with NTSB overlay)

As a result of the crash, the motorcoach driver, two motorcoach passengers, and the driver and codriver of UPS-1 died. About 49 motorcoach passengers were injured (as described later, medical information for all passengers was not available). The FedEx truck driver was not injured, and his codriver had minor injuries. The driver

[7] The occupants of the car declined to be interviewed after the crash.

of the car, the car's two passengers, and the driver and codriver of UPS-2 were not injured.

1.2 Emergency Response

Numerous state and local authorities assisted in the emergency response to the crash. The Pennsylvania Turnpike Commission, which had operational authority over the turnpike, coordinated matters related to highway operations, such as rerouting traffic, through its operations center in Harrisburg. A log of calls to and from the turnpike commission's dispatcher provided details about the emergency response.

The Pennsylvania State Police had primary jurisdiction for investigating the crash. Officers responded to the scene from their station in Greensburg, 7 miles from the crash site. The 911 communications center operated by the Westmoreland County Department of Public Safety in Greensburg dispatched fire and rescue crews during the emergency and fielded emergency calls from motorists on the turnpike as well as motorcoach passengers. The department supplied a chronology of events recorded by the 911 center.

According to the Pennsylvania Turnpike Commission's dispatch records, a maintenance truck driver passing the scene in the opposite direction called to report the crash at 3:33 a.m. Westmoreland County's 911 center was notified of the emergency at 3:34 a.m. and began receiving calls. The crash was classified as a major incident, and by 3:34 a.m., fire and emergency medical service (EMS) crews had been dispatched. At 3:37 a.m., a turnpike commission dispatcher received a report that a tour bus was involved in the crash, with multiple entrapped passengers.

Five volunteer fire departments in Westmoreland County responded to the crash. The chief of the Mt. Pleasant Township Fire Department assumed incident command at 3:36 a.m. (a state police officer took over command at 5:27 a.m.). Mt. Pleasant Township sent four fire and rescue units and 20 firefighters to the scene. Fire departments from the communities of Youngwood, Norvelt, Kecksburg, and Chestnut Ridge (Stahlstown) sent a total of seven fire and rescue units. One rescue unit from Fayette County responded as well.

At 3:36 a.m., Mutual Aid Ambulance Service in Greensburg, which held the contract for ground and air ambulances where the crash occurred, received a call from the Westmoreland 911 center and began dispatching crews. According to the turnpike commission's log, the first ambulance arrived on scene at 3:49 a.m. Ambulances were also provided by 10 EMS agencies in surrounding towns and counties. Altogether, 20 ambulances were sent to the scene. Local hospitals sent doctors to the scene. The first ambulance left the scene at 4:05 a.m., and victims began arriving at area hospitals about 4:50 a.m. (the same time the last ambulance left the scene).[8]

The Pennsylvania Turnpike Commission, in coordination with the state police, implemented emergency procedures to shut down parts of the turnpike and reroute stranded vehicles. Ultimately, all crash-involved vehicles were cleared by 3:10 p.m., and the westbound lanes reopened at 6:25 p.m.

1.3 Injuries

In all, 69 people were involved in the crash, with injuries ranging from none to fatal (see table 1). The driver and two passengers were ejected from the motorcoach and suffered fatal blunt-force trauma injuries. The driver and codriver of UPS-1 also died from blunt-force trauma injuries.

Table 1. Severity of injuries sustained by vehicle occupants.

Occupants	Fatal	Serious	Minor	None	Unknown	Total
Motorcoach driver	1	--	--	--	--	1
Motorcoach passengers	2	9	40	2	6	59
FedEx driver	--	--	--	1	--	1
FedEx codriver	--	--	1	--	--	1
UPS-1 driver	1	--	--	--	--	1
UPS-1 codriver	1	--	--	--	--	1
UPS-2 driver	--	--	--	1	--	1
UPS-2 codriver	--	--	--	1	--	1
Car driver	--	--	--	1	--	1
Car passengers	--	--	--	2	--	2
TOTAL	5	9	41	8	6	69

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

The 57 surviving motorcoach passengers and the FedEx driver and codriver were transported to area hospitals. Survivors with minor injuries sustained contusions and lacerations. Seriously injured passengers sustained fractures, internal chest and

[8] The earliest arrival time in the records was 4:49 a.m. Traffic at the scene initially delayed the ground response. The hospitals were Excela Frick Hospital about 20 miles away, Forbes Hospital about 30 miles away, and UPMC Somerset Hospital about 35 miles away.

abdominal injuries, and head and chest trauma. Because the NTSB did not receive medical records for every patient, the extent of injury for six motorcoach passengers is unknown.

1.4 Survival Aspects

1.4.1 Occupant Protection and Emergency Egress for Motorcoach and Car

Motorcoach. The motorcoach, which was manufactured in 2005, was not equipped with passenger restraints, nor was it required to be. Passenger restraints have been required on motorcoaches since November 2016, after Federal Motor Vehicle Safety Standard (FMVSS) 208, "Occupant Crash Protection" (49 *Code of Federal Regulations* [*CFR*] 571.208), was amended to require lap/shoulder belts for each passenger seating position in (1) all new over-the-road buses and (2) all new buses with a gross vehicle weight rating (GVWR) greater than 26,000 pounds.[9]

The two ejected, fatally injured passengers were sitting in the first row (right side) of the motorcoach. Surviving passengers reported being thrown to the right side of the motorcoach when it overturned. Occupants were further displaced by the strikes from the FedEx truck and UPS-1. The motorcoach driver's seat was equipped with a lap belt. The belt was found unbuckled, undamaged, and in the stowed position in the postcrash examination of the wreckage, with no signs of use such as stretching. Physical evidence indicates that the driver was not belted when the motorcoach hit the embankment.

Four of the seven windows on each side of the motorcoach had latches that could release the windows, allowing them to be used as exits in case of emergency. The motorcoach had a Transpec® roof hatch toward the back. The roof hatch was designed to serve the dual purposes of roof vent and emergency exit. Passengers told the NTSB that they exited through the roof hatch or through an opening the crash had created at the front of the motorcoach. (See section 1.6.1 for a detailed description of damage to the motorcoach.)

[9] (a) The Motorcoach Enhanced Safety Act was passed into law on July 6, 2012, as part of the Moving Ahead for Progress in the 21st Century Act (49 *United States Code* 31136, sections 32701-32711), accessed September 21, 2021. Among the law's provisions was that, within 1 year, the Secretary of Transportation should prescribe regulations requiring "safety belts to be installed in motorcoaches at each designated seating position." The National Highway Traffic Safety Administration (NHTSA) published the final rule amending FMVSS 208 to comply with the mandate on November 25, 2013 (78 *Federal Register* 70416). Compliance was permitted before the effective date of November 28, 2016. (b) 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. Buses with a GVWR greater than 26,000 pounds are commonly called motorcoaches. *Over-the-road buses* are constructed with an elevated passenger deck over a baggage compartment. They are generally used for long-distance bus service and for connecting outlying areas to central cities, with limited stops.

Car. All three occupants of the car were wearing lap/shoulder belts. None of them were injured in the crash, and they declined to be interviewed. No evidence suggested that any airbags deployed in the car.

1.4.2 Protection for Truck Cab Occupants

Title 49 *United States Code* (*USC*), chapter 301, which took effect on January 1, 1968, requires all commercial vehicles (except buses) to be fitted with seat belts in all designated seating positions. The front seats of all three trucks were fitted with lap/shoulder belts. The Federal Motor Carrier Safety Administration (FMCSA) requires drivers of commercial motor vehicles to wear their seat belts (49 *CFR* 392.16). All three truck drivers were wearing their lap/shoulder belts at the time of the crash.

The three Freightliner trucks involved in the crash were equipped with sleeper berths. Restraints on sleeper berths have been required in commercial trucks since 1971 (49 *CFR* 393.76). The systems are intended to prevent occupants from being ejected from the berth when a truck decelerates. The restraints in the trucks involved in the crash consisted of webbed netting, with fixed anchors near the ceiling and buckled anchors on the floor.

The codrivers of the FedEx truck and UPS-2 were in their sleeper berths at the time of the crash, with the safety nets engaged. Because of the extensive damage to the cab of UPS-1, it could not be determined whether the codriver was in the passenger seat or the sleeper berth. The mattress and sleeper berth restraint of UPS-1 were not found in the wreckage.

The right sides of the UPS trucks were marked with a sign reading “Team Operation Check Sleeper in Case of Emergency” (see figure 5). Emergency responders told the NTSB that the markings on the UPS trucks were useful and made them realize that they should look for two occupants in the wreckage of UPS-1.

Figure 5. Right side of UPS-1 showing sign telling emergency responders to check truck's sleeper berth.

1.5.Drivers

1.5.1 Motorcoach Driver

Certification, Licensing, and Driving History. The motorcoach driver held a New York class A commercial driver's license (CDL) issued in 2018, with a nonstudent passenger endorsement and no restrictions.[10] The endorsement allowed him to operate a passenger vehicle equipped to carry more than 15 passengers. The license was scheduled to expire in 2023.

The driver obtained his first CDL in California in 2009. In 2011, he transferred his California CDL to New York. He was required to surrender his out-of-state license but not to take knowledge or skill tests. The driver had one conviction for a traffic violation on his New York driving record, for failure to stop at a stop sign in November 2015. The records do not indicate what type of vehicle he was driving. He

[10] A New York class A CDL permits the holder to operate any commercial motor vehicle with a GVWR of 26,001 pounds or more. Included are vehicles designed to transport 15 or more passengers, vehicles towing a trailer with a GVWR of 10,001 pounds or more, and vehicles carrying hazardous materials.

was convicted for exceeding the speed limit by 14 mph in Pennsylvania in 2019, but the conviction does not appear on his record.[11] He was not listed in the National Driver Register Problem Driver Pointer System.[12]

A public records search showed that the driver was involved in two crashes in 2019. In the first crash, in Jersey City, New Jersey, on July 17, he collided with a car while operating a Z&D motorcoach. The crash was minor and resulted in no injuries. The police report found the driver at fault, but there is no indication that he was cited. In the second crash, on Long Island, New York, on September 14, he struck the vehicle ahead of him while driving a car. No police report or traffic violation was associated with the crash.

Employment Background and Work Schedule. The driver began working for Z&D Tour in May 2019. According to his employment application, he had worked as a delivery driver, driving a two-axle box truck, from 2014 to 2019, and as a motorcoach operator before that. His wife told the NTSB that he drove motorcoaches in China for several years.

The driver worked a rotating schedule for Z&D Tour.[13] His normal route was between New York City and New Stanton, Pennsylvania. Shifts could begin or end in either city. Shifts that began in the evening were generally followed by shifts that began in the early morning, and vice versa (see figure 6). In the 3.5 weeks before the crash, the driver worked 11 consecutive shifts, had a day off (Christmas), worked five more consecutive shifts, then had another day off (New Year's). Then, the driver worked three shifts until the crash.

[11] Information about the case came from the Pennsylvania State Police. The driver pled guilty to improper display of license plate; the speeding violation was dismissed. Because there was no finding of guilt for the speed violation, it does not appear on his driving record. A case adjudicated in Pennsylvania would not necessarily appear on a New York driving record; reciprocity agreements between states typically do not involve non-moving violations.

[12] The Problem Driver Pointer System is a computerized database that contains information about individuals whose privilege to operate a motor vehicle has been revoked, suspended, canceled, or denied or who have been convicted of serious traffic-related offenses. The database is maintained by the National Driver Register, a division in the National Center for Statistics and Analysis under NHTSA.

[13] Employees with rotating schedules work one shift for a certain period (for example, the day shift), then rotate and work another shift (such as the night shift), and then begin the rotation again.

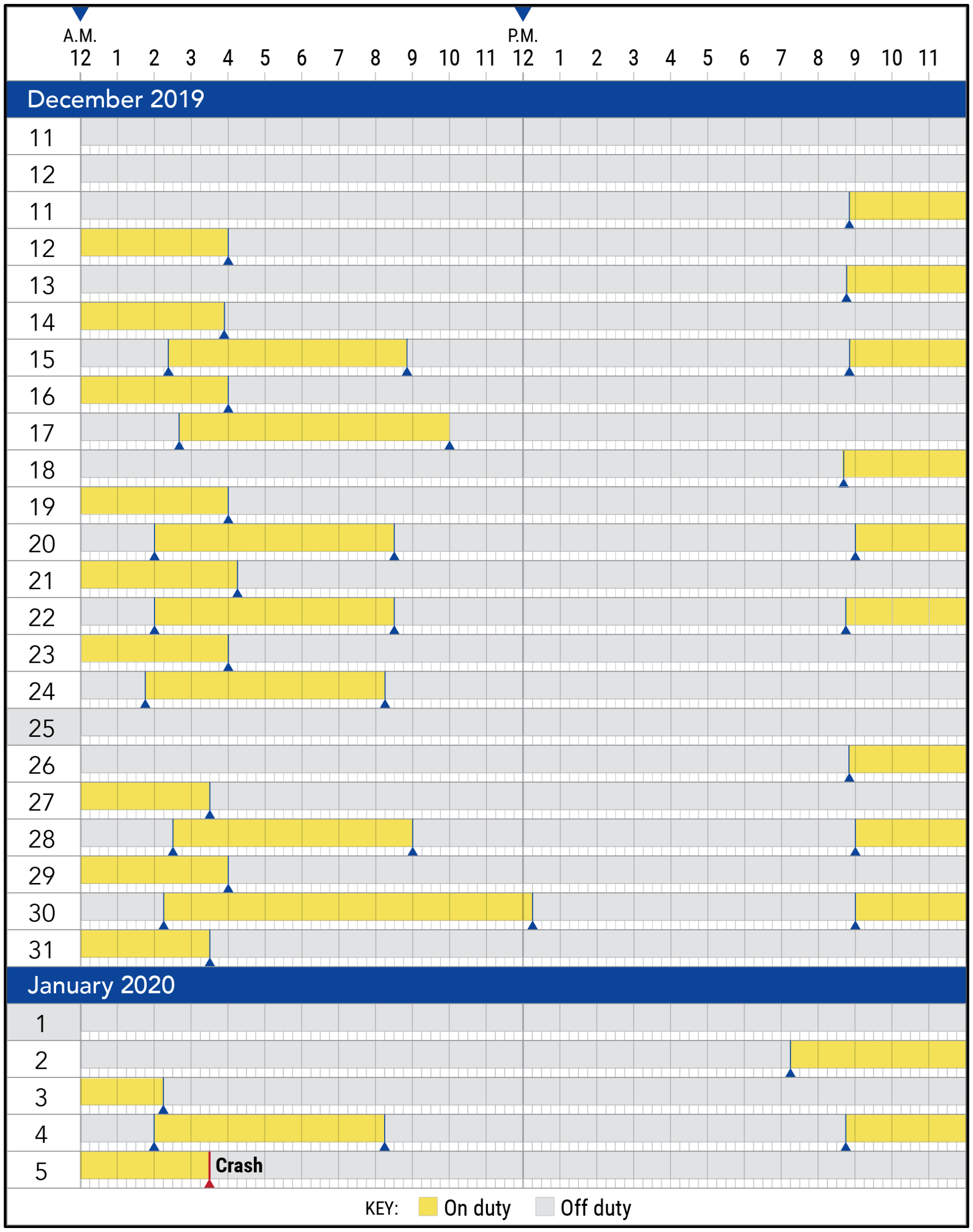

Figure 6. Motorcoach driver's schedule during month before crash.

Precrash Activities. According to the electronic logging device (ELD) in his vehicle, the driver began the first trip of the week the evening of January 2 in Queens, New York, and arrived in New Stanton early on the morning of January 3.[14] He then was off duty for about 24 hours. He began the return trip to Queens at 2:00 a.m. on January 4 and arrived at 8:15 a.m.[15] Afterward, he was off duty for about 12 hours.

[14] The driver had the use of a company-supplied apartment in New Stanton when his shift ended there.

[15] The driver lived in the Flushing neighborhood of Queens.

The driver went on duty at 8:45 p.m. on January 4. According to the company, he was due to arrive in New Stanton between 3:45 a.m. and 4:15 a.m. A relief driver would take over the route in New Stanton and continue to Cincinnati.

According to his cell phone records, the driver did not make or receive any calls or text messages for 18 hours after he went off duty on January 3, and for 10 hours after ending work on January 4.[16] The driver's last recorded call was at 9:34 p.m. on January 4, just before he picked up passengers in Manhattan for the crash trip.

No specific information could be obtained about when the motorcoach driver slept. However, according to his work schedule, he had over 10 hours available for sleep during his off-hours on January 2 and 4, and over 18 hours available on January 3.

Medical History and Toxicology. Commercial drivers in the United States are required by the *Federal Motor Carrier Safety Regulations* (*FMCSR*s) to be certified as physically qualified to drive a commercial vehicle (49 *CFR* 391.41). The motorcoach driver's most recent medical examination to determine his fitness for duty as a commercial driver was conducted on May 31, 2019. The examining physician recorded his height as 5 feet 10 inches and his weight as 200 pounds, resulting in a body mass index (BMI) of 28.7 kilograms per square meter (kg/m^2).[17] The driver reported that he was not taking any medication, did not drink alcohol, and smoked 10 to 20 cigarettes a day. He indicated that he had not been diagnosed with any sleep disorders (his wife told the NTSB that he generally slept well and that she had not observed that he had difficulty falling or remaining asleep). The driver's vital signs, vision, and hearing were found to be within normal limits. He was issued a 2-year medical certificate, with no conditions or restrictions.

The driver's autopsy showed evidence of heart disease but no evidence of damage from reduced or blocked blood flow to the heart muscle. The Pennsylvania Department of Health Bureau of Laboratories, NMS Labs, and the Federal Aviation Administration (FAA) Forensic Sciences Laboratory tested samples of both the driver's blood and his urine. No drugs (except caffeine) were detected in the driver's blood or urine, and no alcohol was identified in his blood.[18]

[16] The driver's cell phone records do not show any data use.

[17] BMI is calculated by dividing weight by the square of body surface area. BMI results between 25 and 30 indicate overweight; results above 30 indicate obesity. BMI is expressed in units of kg/m^2.

[18] Caffeine was detected by NMS Labs. The Pennsylvania Department of Health Bureau of Laboratories tests for ethanol (alcohol), amphetamine, barbiturates, benzodiazepine, benzoylecgonine, buprenorphine, methylenedioxymethamphetamine (MDMA [Ecstasy or Molly]), methadone, methamphetamine, opiates, phencyclidine (PCP), tetrahydrocannabinol (THC [cannabis]), and tricyclic antidepressants. The FAA laboratory tests for more than 1,300 drugs.

1.5.2 FedEx Driver

Certification, Licensing, and Driving History. The FedEx truck driver held a California class A CDL that was issued in 2015 and was due to expire in 2020. He had endorsements for double and triple trailers, passenger transportation, school buses, and tank vehicles. He obtained his first CDL in 2010 and told the NTSB that he had trained at a truck-driving school in Rialto, California. He held five driver positions with operators regulated by the US Department of Transportation (DOT) after obtaining his California CDL.

The driver's California driving record did not list any violations or crashes. A public records search revealed a crash on October 8, 2015. On the candidate information sheet provided by FedEx, the driver listed a "non-preventable crash" while driving a school bus in California on January 15, 2016; the crash resulted in minor damage and no injuries.

Employment Background and Work Schedule. FedEx contracts with other companies for drivers and trucks. Sioux Trucking, Inc., of Santa Rosa Valley, California, owned the truck involved in the crash. The driver had been employed by Sioux since April 13, 2018. He was normally assigned to the truck involved in the crash and typically drove a route between California and the East Coast.

The driver had varying days off and mostly worked overnight. In the days before the crash, he worked 2 days, had 2 days off, and then worked 4 consecutive days before the crash. While working consecutive days, the driver's off-duty sleep took place in the truck's sleeper berth. The driver stated in his NTSB interview that he slept well in the sleeper berth.

Precrash Activities. Information about the driver's precrash activities were gathered from the ELD in his truck, cell phone records, the inward-facing video recording, and an NTSB interview. According to the ELD, the driver was off duty on January 1. The crash trip began at 8:51 a.m. on January 2 in San Bernardino, California. The driver took over from the codriver at 9:16 p.m. when they reached Kingman, Arizona, and drove until 8:30 a.m. on January 3, when they reached Tucumcari, New Mexico. He went on duty at 8:14 p.m. on January 3 in Springfield, Missouri, and drove until 6:59 a.m. the next day, when they reached Jefferson Township, Ohio. He went on duty at 5:57 p.m. in South Amboy, New Jersey, on January 4 and began the return trip.

According to his cell phone records, the driver did not make or receive any calls or text messages after 1:31 a.m. on January 5. The video recording, from the inward-facing camera mounted inside the truck's windshield, shows the driver wearing headphones. He told the NTSB that he was listening to music on the headphones. Driving while wearing headphones is illegal in Pennsylvania, where the crash occurred, and in California, where the driver was licensed.[19]

Medical History and Toxicology. The driver last underwent a medical certification examination on July 22, 2019. He reported using no medication. No significant abnormalities were noted, and he was issued a medical certificate valid for 2 years, with no conditions or restrictions.

The driver underwent random DOT tests for alcohol and drugs on May 14, 2019, and August 7, 2019, with negative results.[20] After the crash, the driver underwent DOT-mandated breath testing for alcohol and urine testing for drugs. The results were negative.

1.5.3 UPS-1 Driver

Certification, Licensing, and Driving History. The driver held a Pennsylvania class A CDL with endorsements for double and triple trailers, passenger transportation, school buses, and tank vehicles. His license was issued in 2018 and was due to expire in 2022. He obtained his first CDL in 1991.

The driver's Pennsylvania driving record shows seven traffic violations before 2009 and a crash in a commercial truck in 2012, for which the record gives no details.[21] UPS records show that the driver had a crash while operating a commercial truck on Interstate 70 in East Washington, Pennsylvania, on May 30, 2019. He struck the back of a vehicle that had come to an abrupt stop. No injuries were reported in the crash.

Employment Background and Work Schedule. According to records in the driver's UPS file, he began driving commercial vehicles in 2011. He worked as a loader/driver for a commercial farm from September 2012 to May 2014. He then

[19] Pennsylvania vehicle code, Title 75 "Vehicles," section 3314, "Prohibiting use of hearing impairment devices": "No driver shall operate a vehicle while wearing or using one or more headphones or earphones"; California vehicle code, "Headsets and Earplugs," 27400: "No person operating a motor vehicle or bicycle may wear earphones, earplugs or a headset that covers, rests in or is inserted in both ears." According to the FMCSA, CB radios and earphones are not prohibited by regulations, as long as such devices do not distract the driver and the driver is capable of complying with 49 *CFR* section 391.41(b)(11). FedEx has a policy prohibiting the use of earphones.

[20] DOT urine testing for drugs identifies metabolites of amphetamine, methamphetamine, cocaine, codeine, morphine, heroin, PCP, MDMA, methylenedioxyamphetamine, methylenedioxyethylamphetamine, THC, oxycodone, oxymorphone, hydrocodone, and hydromorphone.

[21] As part of its investigation, the NTSB obtained a full driving history but deemed only the past 10 years to be pertinent to the crash. More information about the driver's history can be found in the NTSB public docket for this investigation (case number HWY20MH002).

worked as a part-time driver for UPS from May 2012 to October 2014 and began working as a full-time UPS driver in November 2014.

According to the ELD in his truck, the driver was part of a two-person team during the month leading to the crash. His route took him to and from Pennsylvania, Ohio, West Virginia, Virginia, Arkansas, and New York. The ELD showed that his shifts were mostly at night. The shifts tended to begin sometime between 7:00 p.m. and midnight and usually ended sometime between 7:00 a.m. and 9:00 a.m. While working consecutive days, his off-duty sleep was in the truck's sleeper berth.

Precrash Activities. The driver was off duty for 6 consecutive days before the crash. According to the ELD, he went on duty at 12:16 a.m. on January 5 and began driving at 1:04 a.m. According to his cell phone records, he did not make or receive calls or text messages after his shift began on January 5.

Medical History and Toxicology. The driver's most recent medical certification examination was on October 25, 2019. He reported using prescription lisinopril to treat high blood pressure and having had a kidney removed in 2018. No significant abnormalities were identified. He was issued a medical certificate valid for 1 year because of his high blood pressure.

The autopsy report identified moderate atherosclerotic stenosis of the left anterior descending coronary artery and hypertensive cardiovascular disease.[22] Records from the driver's primary care provider for the 3 years preceding the crash showed that he had longstanding high blood pressure and early disease in his remaining kidney. Beginning in February 2019, he complained of chronic aching in his bones and was prescribed duloxetine.[23] He told his providers that the drug worked well to control his symptoms.

Toxicology tests performed by NMS Labs on pooled blood obtained during the autopsy identified ethanol (alcohol) at 0.013 grams per deciliter (gm/dL), duloxetine at 130 nanograms per milliliter, and caffeine. Tests at the FAA's Forensic Sciences Laboratory identified ethanol at 0.012 gm/dL, with N-propanol alcohol in cavity blood but no ethanol in vitreous. The results indicate that ethanol most likely

[22] *Atherosclerotic stenosis* is plaque buildup causing narrowing of the arteries.

[23] Duloxetine is a prescription medication that is indicated for the treatment of depression, anxiety, nerve pain, and chronic musculoskeletal pain. Information is limited about whether or how much duloxetine might impair users' cognition or psychomotor functioning. Here is the instruction given to prescribers: "Although in controlled studies duloxetine . . . has not been shown to impair psychomotor performance, cognitive function, or memory, it may be associated with sedation and dizziness. Therefore, caution patients about operating hazardous machinery including automobiles, until they are reasonably certain that duloxetine . . . therapy does not affect their ability to engage in such activities" (National Institutes of Health, US National Library of Medicine, DailyMed, Duloxetine (accessed June 1, 2021).

came from postmortem production in tissues due to microbial action, rather than through ingestion. The laboratory identified duloxetine in samples of cavity blood and in the liver.[24]

1.5.4 UPS-2 Driver

Certification, Licensing, and Driving History. The driver held a New Jersey class A CDL endorsed for tankers and double and triple trailers. The license was scheduled to expire in 2020. He obtained his first CDL in 1979 after training in Oklahoma.

His driving record showed one conviction in 2013 in Connecticut for obstructing the passage of another vehicle. No records of previous crashes involving the driver were found.

Employment Background and Work Schedule. The driver was hired for a full-time driving position by UPS on September 25, 2005. According to his employment records, he had worked for four other carriers between 1994 and 2005. He told the NTSB that he had been driving on the section of the Pennsylvania Turnpike where the crash occurred for 3 years. He was part of a two-person driving team in the month before the crash. He said that his days off varied, but that his shifts most often began in the afternoon or evening and were about 10 hours long.

Precrash Activities. The driver told the NTSB that he was off duty for 4 consecutive days before the crash, beginning December 31, 2019. He said that during his time off, he went to bed between 10:00 and 11:00 p.m. and got up about 8:00 a.m. every day.

He began his first shift after being off duty on January 4. He told the NTSB that he took a nap starting at 3:00 p.m. before getting ready for work at 9:00 p.m. He said that he began the shift in Willow Grove, Pennsylvania, picked up a trailer in Philadelphia, and was on his way with his codriver to deliver the trailer in Louisville, Kentucky. According to his cell phone records, the driver did not make or receive any calls or text messages after 1:56 a.m. on January 5.

Medical History and Toxicology. The driver's most recent medical certification examination was on September 2, 2019. He reported no use of medications and no medical conditions. The medical examiner noted that he had

[24] As required by statute, the Pennsylvania Department of Health Bureau of Laboratories tested heart blood obtained during the UPS-1 driver's autopsy. However, results were inconsistent with those from the other laboratories. Methamphetamine was identified in the samples analyzed by the state laboratory but not in the samples analyzed by either of the other two laboratories, indicating that the specimens tested by the state laboratory did not come from the UPS-1 driver. For more information, see the NTSB medical officer's report in the public docket for this investigation.

high blood pressure treated with hydrochlorothiazide and lisinopril and high cholesterol treated with atorvastatin. The driver was issued a medical certificate valid for 1 year because of his high blood pressure.

After the crash, the driver underwent DOT-mandated breath testing for alcohol and urine testing for drugs. The results were negative.

1.5.5 Car Driver

The Pennsylvania State Police did not suspect impairment or intoxication and did not perform or request tests on the driver of the car. No further information about the driver was available.

1.6 Vehicles

1.6.1 Motorcoach

General. The 57-passenger model C2045 Van Hool motorcoach was manufactured in March 2005 and placed into service in May 2005. The motorcoach was 45.6 feet long and had a GVWR of 50,700 pounds. It was equipped with a Detroit Diesel Corporation series 60 14.0-liter diesel engine, ZF (now Bosch) steering gear, and an Allison B500RM 6-speed automatic transmission. It was also equipped with 315/80R 22.5 tires, mounted on 22.5 x 9.00 steel wheels, and Wabco air-operated antilock disc brakes on all axles.

The transmission and engine were mounted at the rear of the motorcoach. The engine's performance, fuel efficiency, and emissions were controlled by a Detroit Diesel Electronic Control (DDEC) V engine control module (ECM).[25] The ECM also recorded diagnostics associated with engine or sensor faults that could activate warnings on the vehicle's dash, as well as recording vehicle and engine speed and last-stop and hard-brake events, if certain thresholds were met.

The engine was equipped with a Jacobs engine brake, also known as a compression brake, which is a type of engine retarder designed to help slow a vehicle and reduce the need to use the service brakes (the primary brakes, operated by a foot pedal). When an engine brake is activated, it reduces the power from the engine by opening the cylinder exhaust valves near the top of the compression stroke. That releases the combustion gases through the exhaust instead of driving the pistons to the bottom of the cylinders. The engine then acts like an air compressor, drawing air in and pushing air out. The cylinders are powered by the forward

[25] An ECM is a computer that monitors multiple engine sensors, allowing it to adjust and control engine performance based on real-time conditions. Engine manufacturers can employ one or more ECMs to manage engine performance. ECMs can also interact with electronic control systems that regulate other vehicle operations such as brakes and transmission.

momentum of the drivetrain. That increases the drag on the vehicle, allowing it to slow without using the service brakes. The engine brake acts only on the drive wheels, which in the trucks involved in the crash were the rear wheels.

To activate the engine brake, the driver first manipulates a three-position switch, located on the instrument panel, from the "off" position to either a 50 percent or 100 percent position, according to the level of engine braking desired. Engine braking begins when the driver removes his foot from the accelerator pedal. Stepping on the accelerator pedal deactivates the engine brake until the driver lifts his foot off the pedal again. The extensive damage to the front of the motorcoach prevented the NTSB from determining from the physical evidence whether the engine brake switch (located in the instrument panel) was on or off.

Maintenance and Inspection. The motorcoach's most recent annual inspection was performed on July 10, 2019, by Golden Bus of Brooklyn, New York, which also performed routine maintenance on the vehicle. The mechanic passed the motorcoach after installing a new exhaust gasket and replacing a fitting on the suspension system. At the time of the crash, the motorcoach's odometer read 751,637 miles.

Postcrash Inspection. Because of the extensive crash damage at the front of the motorcoach, a functional check of the complete steering system could not be performed. The steering wheel and column were retrieved from the crash debris and inspected. The steering wheel ring was damaged and bent, and the ring cover was cut and torn. No defects were found in the tie rods, ball joint connections, or steering knuckles. The steering gearbox was removed and later tested by Bosch Automotive Steering, the manufacturer. Bosch found no abnormalities.

Also because of the crash damage, aspects of the brake system (check valves, low pressure warning, brake pedal application, air compressor operation, pushrods, and air leakage) could not be tested. No precrash defects were found in the brake pedal and treadle valve assemblies. The brake rotors were measured and found to exceed the manufacturer's minimum thickness on all axles. The brake linings were visually examined and did not reveal any worn or defective foundation brake components.[26] No measurements were taken.

The NTSB found no visible damage to the motorcoach's suspension system and no precrash-related defects (such as cracks) on any of the wheels. The left- and right-side tires on the steering axle (axle 1) had minor abrasions on the outboard shoulders. Abrasions on the outer sidewall of the right tire on axle 2 extended from the tire bead to the shoulder. The tires were specified by the motorcoach manufacturer to be inflated to

[26] *Foundation brakes* are the various components of the braking system, including the brake drum and brake shoes, that are found at the end of each axle.

120 pound-force per square inch (psi) for axle 1, to 95 psi for axle 2, and to 110 psi for axle 3.[27] All the tires were found inflated after the crash, as shown in table 2. The NTSB measured the average depth of the tire treads, also shown in the table. All tread depths were above the minimum (4/32 inch for the steering axle, 2/32 inch for the remaining axles) specified at 49 *CFR* 393.75.[28] There was no evidence that the tires lost air due to the crash events.

Table 2. Motorcoach tire pressure and tread depth postcrash.

Tire	Pressure (psi)	Tread Depth (in.)
Axle 1, left	95	9/32
Axle 1, right	95	10/32
Axle 2, left	92 (outside) 110 (inside)	4/32 (outside) 6/32 (inside)
Axle 2, right	96 (inside) 102 (outside)	5/32 (inside) 10/32 (outside)
Axle 3, left	115	16/32
Axle 3, right	88	10/32

The antilock braking system (ABS) sensors, modulators, and wiring were intact. The ABS light function could not be verified because of the crash damage to the instrument panel and wiring. The electrical system could not be examined due to the crash damage. The bulbs for the taillights showed signs of hot shock.[29] The bulbs for the brake lights showed no signs of damage.

The engine compartment at the rear of the motorcoach was covered with oil and dirt and with dirt and debris compacted onto the crankshaft and flywheel as well as into the exhaust pipes. The air compressor and radiator were displaced forward, and the engine cooling fans and left engine mount were broken. The transmission was intact, with no signs of an internal malfunction. The drive axle housing appeared to be undamaged and showed no signs of internal malfunction.

Exterior Damage. The motorcoach sustained extensive damage to the exterior, most severely at the front, right side, and back. The entire front end was

[27] The manufacturer's label was found mounted to the motorcoach's stepwell. The label listed specifications for tires and wheels.

[28] The regulation specifies that tread depth shall be measured in a major groove at any location on the tire and not where tie bars, humps, or fillets are located.

[29] *Hot shock* is a sign that a vehicle's lights were on at the time of a crash. The tungsten-based filament in a bulb softens at high temperatures and can be stretched when the bulb is abruptly accelerated during a crash. The stretching is called hot shock.

separated and displaced, including the dashboard and windshield, steering wheel, loading door, and loading stairs. The front overhanging structure appeared to have separated from the vehicle when it was recovered from the crash scene. The right sidewall was intact, but damage extended over much of the right side. Damage at the rear of the motorcoach was concentrated at the bottom, with extensive deformation inward at the engine. The upper portion of the aft end was intact (the region above the passenger floor).

Photographs taken at the scene show the motorcoach's front structure twisted and entangled with the front of the FedEx truck (see figure 7). A point cloud image of the postcrash motorcoach was rendered from three-dimensional scans (see figure 8).[30]

Figure 7. Photograph of collision scene showing front of motorcoach rolled onto its right side and entangled with front of FedEx truck. (Source: Pennsylvania State Police)

[30] To create a *point cloud*, an object or scene is first scanned at many specific points. The spatial measurements (x, y, and z coordinates) and sometimes color values for the scanned points are then combined to represent the object or scene as a whole.

Figure 8. Point-cloud image of motorcoach postcrash, with inset photo of intact motorcoach of same model.

Damage to the windows was most severe on the right side of the passenger compartment, with multiple windows damaged and dislocated. All the windows were double-paned, and in the two windows at the front of the bus (both emergency exit windows), only the outer panes were broken. Mud and debris were found on all the driver-side windows.

Interior Damage. The driver's seat at the front of the motorcoach was separated from the passenger seats by a privacy panel. The seat was air-suspended and equipped with a lap belt. The crash exposed the front of the motorcoach forward of the privacy panel on the passenger side and the driver's seat, which was still attached to the floor (see figure 9). The lap belt was unbuckled and undamaged.

Figure 9. Driver seat displaced and exposed at front of motorcoach. (Photo was taken at storage facility after vehicle was uprighted and moved from crash scene.)

The motorcoach was configured with 14 rows of double passenger seats on the left (driver's) side and 13 rows of double passenger seats on the right (see figure 10). The back of the motorcoach had a row of triple passenger seats on the left and a restroom on the right. Damage to passenger seats included displaced seatbacks or headrests and displaced, deformed, or broken armrests. All the seats were attached to the motorcoach floor postcrash. Although the luggage racks above the seats on the driver and passenger sides were damaged in the crash, they remained attached and did not intrude into the occupant space.

Figure 10. Motorcoach interior viewed from back toward front. Passenger belongings were put inside the vehicle after emergency crews found them strewn on highway after crash. (Photo was taken at storage facility after vehicle was uprighted and removed from crash scene.)

1.6.2 FedEx Truck

General. The FedEx truck-tractor was a 2018 Cascadia model manufactured by Freightliner, a Daimler Trucks North America brand based in Portland, Oregon.[31] The truck had a GVWR of 52,350 pounds and was equipped with a 455-horsepower (hp) Detroit DD15, 14.8-liter diesel engine, a DT12-1650-OH1 HD 12-speed transmission with overdrive, and Wabco 6S/6M air-operated antilock drum brakes. The truck was hauling a 53-foot-long 2019 Translead semitrailer manufactured by Hyundai that had a GVWR of 68,000 pounds.

Detroit Assurance Safety System. The FedEx truck was equipped with version 4.0 (the successor to version 2.0) of the Detroit Diesel Corporation safety system called Detroit Assurance®.[32] The system uses a bumper-mounted radar unit to monitor objects ahead. Included in version 4.0 are active brake assist (Daimler's name

[31] The model is also referred to as a "new" Cascadia or the third-generation Cascadia.

[32] Detroit Diesel Corporation is a subsidiary of Daimler Trucks North America. In 2015, Daimler introduced the Detroit Assurance system. Version 2.0 became available on Freightliner's Cascadia trucks in 2015. In the 2017 model year, Freightliner began installing Detroit Assurance version 4.0 on its Cascadia trucks. In 2018, AEB became standard on its Cascadia trucks.

for its automatic emergency braking [AEB] system), adaptive cruise control, and tailgate warning.

When the radar senses that the truck is too close to another vehicle or object, the safety system initiates active brake assist.[33] Active brake assist is always on, but it operates only in the absence of driver input (that is, if the driver does not respond to another vehicle or object and brake with sufficient force). Version 4.0 of the system supplies full braking in response to moving, stopped, or stationary objects. *Moving objects* are defined as vehicles that are moving but are slower than the approaching vehicle, *stopped objects* as vehicles that are moving but come to a stop while being detected by the approaching vehicle's radar, and *stationary objects* as parked or stopped vehicles in the vehicle's path for which the radar does not detect movement. According to Daimler's published information for version 2.0, the radar can detect "any metallic object, but the system only reacts to cars, trucks, and motorcycles."[34] Pedestrian detection was added to active brake assist in version 4.0 and requires a forward-facing video camera. Pedestrians must be in motion and remain in motion to be detected, and vehicle speed must be below 25 mph.

Adaptive cruise control automatically adjusts a truck's cruising speed to maintain a set following distance behind a lead vehicle. If the lead vehicle causes the truck to stop for 2 seconds or less, the system resumes motion once it senses enough road ahead.[35] The system operates by using fused radar and camera technology.

The tailgate warning system activates a signal on the dash to alert drivers if they follow another vehicle too closely while traveling over 20 mph. The tailgate warning system is independent of active brake assist and adaptive cruise control.

Detroit Assurance commands a truck's service brakes, engine, and transmission when collision mitigation or avoidance is necessary. It can track and identify up to 40 objects at once and identify the top six immediate risks. When reviewed postcrash, the data from the FedEx truck did not reveal any crash-related information and showed that the system was functioning normally.

The FedEx truck was not equipped with Detroit Assurance's optional lane departure warning system. The truck was equipped with a Lytx DriveCam system mounted on the windshield that included forward-facing and inward-facing video,

[33] The radar on version 4.0 has a range of up to 825 feet compared with 660 feet in version 2.0, according to Daimler brochures on Detroit Assurance (version 2.0 and version 4.0; accessed July 20, 2021).

[34] See link to version 2.0 brochure in previous footnote.

[35] See Detroit Safety Vocational Demand Detroit | Demand Detroit (accessed September 21, 2021) for descriptions of the individual systems. Additional details can be accessed through the site's search function.

but it was not part of the Detroit Assurance system.[36] The DriveCam footage showed the FedEx driver actively braking before the crash.

Maintenance and Inspection. The truck's last annual inspection was on November 19, 2019. On December 30, 2019, the California Highway Patrol conducted a roadside inspection of the truck-tractor and its semitrailer and found no violations or vehicle defects. Maintenance records provided by FedEx complied with the *FMCSR*s applying to inspection, repair, and maintenance (49 *CFR* 396.3[b]).

Damage. Photographs taken at the scene show that the semitrailer had separated from the truck-tractor during the crash (see figure 11). At final rest, the trailer was on the median barrier and the truck-tractor was several feet west of the trailer, on the left shoulder and in the left travel lane.

Figure 11. Photograph taken at scene showing damage to FedEx truck. (Source: Pennsylvania State Police)

[36] The Lytx DriveCam system is a video event recorder system with a driver monitoring and recording device mounted on the vehicle windshield. It continually tracks driving performance metrics and records pertinent information when triggered by critical events, such as stability control or hard braking. The Lytx DriveCam has forward- and inward-facing cameras, an integrated omnidirectional microphone, a 9-axis accelerometer, built-in motion sensor, and built-in GPS. When a lateral or longitudinal acceleration threshold is exceeded, referred to as a triggered event by the manufacturer, about 12 seconds of data is recorded, beginning at 8 seconds before the event and continuing for 4 seconds after. The speed recorded by the Lytx DriveCam system is derived from GPS position data. The system also records elapsed event recorder time, which may need correlation to real clock time.

The NTSB examined the truck-tractor and semitrailer at the tow yard after the crash. The hood, bumper, and fenders at the front of the truck showed substantial contact damage. The floorboard on the left side of the cab was buckled against the brake and accelerator pedals. The rear of the sleeper berth was crushed forward. All the air-line connections were broken at the rear of the sleeper berth, and the frame rails and crossmembers were bent. The fifth-wheel plate was displaced forward, and the locking fingers on the slider rail were bent forward.

The front of the semitrailer had contact damage and puncture holes. The front was displaced backward, and the leading edge of the roof was buckled. The right rear of the semitrailer also had significant impact damage. The cargo doors, steel door frame, rear bumper, and rear impact guard were missing. The wooden floor was broken and splintered, the crossmembers were buckled, and the tandem slider rails were twisted.

No obvious precrash damage or defects were found in the truck's steering system. The leaf spring tips on the right side of axle 3 were broken. A visual examination did not find any worn or defective foundation brake components.

No damage was detected with the semitrailer's suspension, tires, or wheels. The ABS sensors, wiring, and modulators on the semitrailer were intact.

1.6.3 UPS-1

General. UPS-1 was a 2018 model Freightliner Cascadia truck-tractor towing a 2018 model 53-foot Stoughton semitrailer with a GVWR of 70,000 pounds. It had a GVWR of 53,220 pounds and was equipped with a Detroit DD13, 12.8-liter, 470-hp diesel engine and a DT12-OB-1650 heavy-duty 12-speed automatic transmission with overdrive. It was also equipped with a Wabco 4S/4M air-operated ABS with hill-start aid, automatic traction control, and an automatic traction control off-road switch. UPS leased the truck from Penske Truck Leasing.

Detroit Assurance Safety System. UPS-1 was equipped with version 2.0 of the Detroit Assurance safety system. Version 2.0 offered full braking in response to moving or stopped objects and partial braking for stationary objects (AEB). UPS-1 was equipped with a forward-facing camera that provided input to the lane departure warning system. The camera tracked the position of the vehicle and sounded a warning if it moved out of the travel lane without activating a turn signal.

Data downloaded from UPS-1 after the crash revealed a fault in the radar unit that affected the radar's alignment and calibration. Daimler determined that the fault first appeared on June 2, 2019, and had been active since then. UPS-1's Detroit Assurance system was therefore nonfunctional at the time of the crash. See "Maintenance and Inspection," below, for more information.

Damage. The truck-tractor sustained catastrophic damage (see figure 12) from striking the FedEx trailer and from its own trailer striking the back of the cab. The left side of the cab and sleeper berth were torn open, and the remaining cab shell skewed toward the right. At final rest, the trailer was "jackknifed" into the sleeper berth.

Figure 12. Photograph taken at scene showing damage to UPS-1 cab.(Source: Pennsylvania State Police)

The NTSB examined the wreckage at the tow yard where it was taken after the crash. The A-pillar of the cab was displaced, with damage extending along the left fuel tank and wheel assemblies.[37] The entire left side of the cab and sleeper berth was torn open. The driver's seat was displaced to the right, and all interior driver controls were damaged or missing (see figure 13).

[37] The *A-pillar* is an upright structural piece that supports the windshield and the front of the roof.

Figure 13. Damage to interior of UPS-1 cab, showing position of driver's seat and destruction to controls.

The truck's electrical and air systems were compromised. The left fuel tank was ruptured, with only a trace amount of fuel remaining in the bottom. The right fuel tank had not ruptured and contained fuel. The front of the semitrailer sustained impact damage, and openings had been torn into the left sidewall, where a 4-foot hole exposed the cargo inside. Gouges and tears were found along the top left edge of the trailer.

Maintenance and Inspection. Personnel at the Penske maintenance facility in Harrisburg, Pennsylvania, performed regular inspections of UPS-1 and carried out most vehicle repairs. The maintenance interval for UPS-1 was every 45,000 miles, according to the Penske vice president of maintenance who oversaw the UPS account. Maintenance would ordinarily be done every 60 to 75 days.

Penske provided the NTSB with copies of maintenance records, diagnostic reports, and repair orders from June 2019 until the date of the crash. Penske's records show that an active fault in the truck's Detroit Assurance system was found during an inspection on July 26, 2019. The fault was also found on September 12, November 22, and December 7. The mechanic noted on the December 7 work summary form: "Radar warning light on; has code in dash for active brake assist unavailable." He noted the correction as "repair wiring harness–main collision mitigation system." He also noted: "Hooked up to unit. Unit had radar codes, but driver didn't write up for issue. Have to get truck scheduled in to sub out." No repairs were made.

1.6.3 UPS-2

General. UPS-2 was a combination vehicle consisting of a 2018 Freightliner Cascadia model truck-tractor towing a 2020 model 28.5-foot Stoughton semitrailer with a GVWR of 40,000 pounds. The UPS-2 truck-tractor had a GVWR of 53,220 pounds and was equipped with a 470-hp Detroit DD13, 12.8-liter diesel engine and a DT12-OB-1650 heavy-duty 12-speed automatic transmission with overdrive. It was also equipped with a Wabco 4S/4M air-operated ABS with hill-start aid, automatic traction control, and an automatic traction control off-road switch. UPS-2, like UPS-1, was leased from Penske Truck Leasing.

Detroit Assurance Safety System. UPS-2 was equipped with version 2.0 of the Detroit Assurance safety system, as described above for UPS-1. UPS-2's system included a forward-facing camera for the optional lane departure warning system. A review of the truck's data after the crash revealed no abnormalities or crash-related information.

Damage. At final rest, UPS-2 was angled off the roadway and positioned on the right shoulder against the embankment (see figure 14). The unit remained coupled. The truck-tractor and semitrailer were examined at the tow yard after the crash. Damage was limited to the front and left side of the truck. Dirt and debris were found on the front axle, scrapes and gouges were noted on the driver's side. The left fuel tank was dented but not otherwise damaged. The top mount for the shock absorber at the right rear of the cab was broken. No other damage was identified.

Figure 14. UPS-2 run up against embankment, with UPS-1 on left. (Source: Pennsylvania State Police)

1.6.5 Car

The four-door Mercedes-Benz model C280W4 car was manufactured in 2007. Its curb weight was 3,460 pounds**.** At final rest, the car was wedged between the right side of the UPS-1 trailer and the left fuel tank and cab of UPS-2 (see figure 15). When examined at the lot where it was taken after the crash, the car exhibited minor-to-moderate damage and deformation.

Figure 15. Final rest position of car wedged between UPS-1 (left) and UPS-2 (right). (Source: Pennsylvania State Police)

The car was equipped with frontal airbags and seat belt pretensioners. The airbags did not deploy during the crash, and no data were available for that car's model year.

1.7 Highway Information

The crash occurred on the westbound Pennsylvania Turnpike, just beyond a left curve with a total length of 1,799 feet and a radius of 1,296 feet (see figure 16). The curve had a downgrade slope of 3 percent and a superelevation of 8 percent.[38]

[38] *Superelevation* is the slope between the inner and outer edges of a roadway. The slope counteracts the centrifugal force acting on a vehicle and reduces its tendency to skid or overturn. In the westbound lanes of the Pennsylvania Turnpike at the crash site, the 8 percent superelevation sloped toward the median.

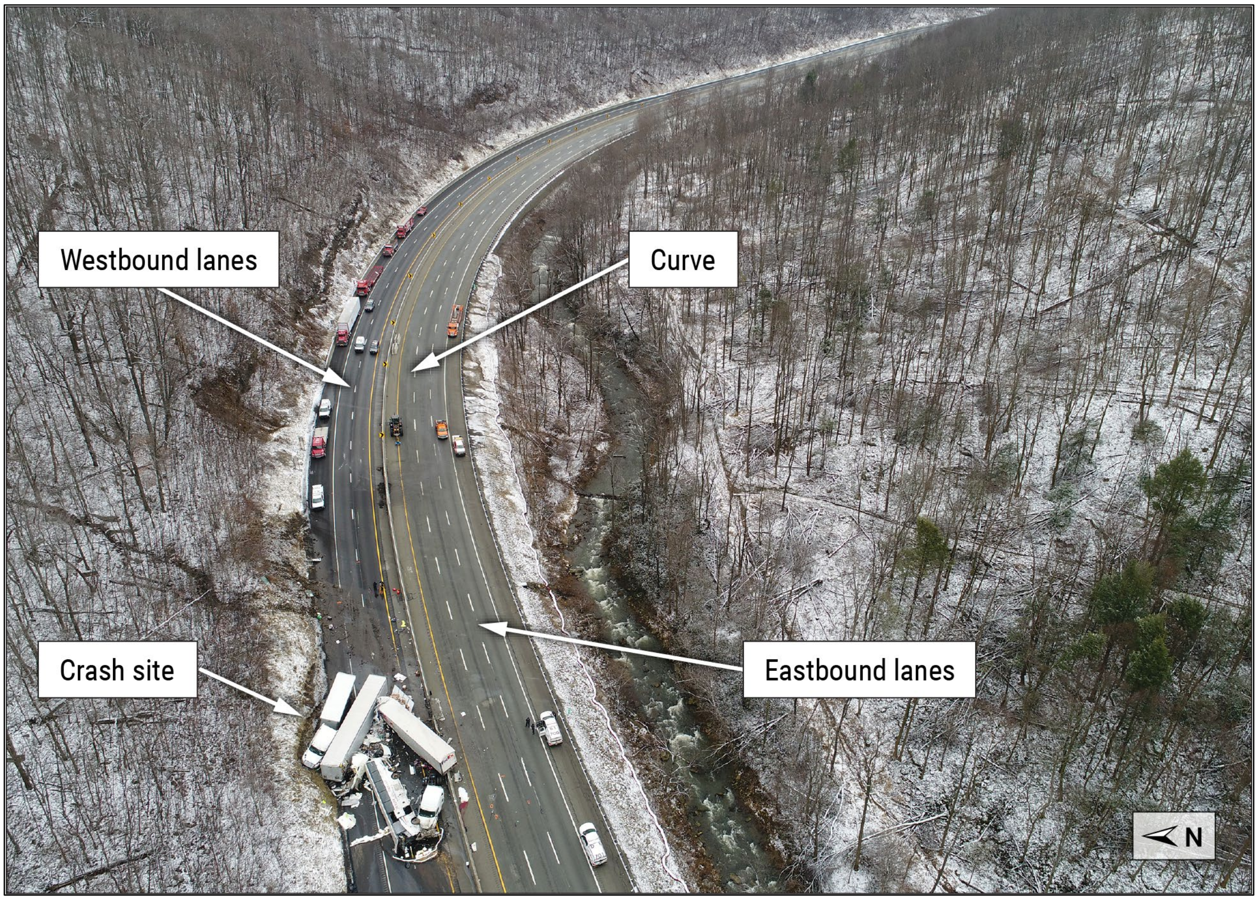

Figure 16. Aerial view of crash scene showing curve and west- and eastbound travel lanes. (Source: Pennsylvania State Police with NTSB overlay)

1.7.1 Construction

The section of the Pennsylvania Turnpike where the crash occurred was designed in 1938 and built in 1939–1940. It was reconstructed and widened in 2005 and resurfaced most recently in September 2019. The roadway consisted of two westbound travel lanes and three eastbound lanes, each 12 feet wide. The westbound lanes had a 12-foot-wide shoulder on the right side and an 8-foot-wide shoulder on the left. A concrete barrier separated the westbound and eastbound lanes. The barrier consisted of interconnected precast concrete segments 52 inches high and 12 feet long.

A slope had been cut into the hillside next to the highway during construction. A concrete barrier 52 inches high had been built against the slope, next to the outside shoulder, along the curve in the westbound direction. The barrier ended 377 feet east of the crash site. Drainage grates along the paved shoulder captured stormwater runoff from the cut slope, and the shoulder was angled toward the cut slope, keeping stormwater from encroaching into the travel lanes.

Grooved rumble strips were set into both paved shoulders westbound. Temporary white lines separated the two westbound travel lanes from each other and the paved shoulder from the rightmost travel lane.[39] The paved shoulder and the leftmost travel lane were separated by a solid yellow line.

In 2011, half an inch of microsurface material was applied over the pavement's wearing course. The resurfacing project in 2019 removed the microsurface material and replaced the existing wearing course on the westbound lanes with a new, 2-inch stone matrix.

1.7.2 Tests on Westbound Lanes

Pavement Friction. After the crash, the NTSB contracted with Applied Research Associates (ARA) to conduct pavement friction tests in the westbound lanes of the Pennsylvania Turnpike near milepost 86.1 (the crash site). The purpose of friction tests is to determine the resistance offered by the pavement surface to the tires when a vehicle brakes, and therefore the pavement's resistance to skidding. Section 1.11 describes an NTSB simulation using the results of the friction tests.

ARA performed the friction tests on July 26, 2021, using ribbed and smooth testing tires that conformed to ASTM standards.[40] The water depth was 0.02 inches. In both lanes, a ribbed tire was used in the left wheel path, and a smooth tire was used in the right wheel path. Tests were conducted at 40, 50, 55, 60, and 70 mph, using a locked-wheel skid friction tester that was in compliance with ASTM E-274.[41] ARA had last calibrated the equipment on June 18, 2021.

Friction numbers in the left lane averaged 53.0 to 43.3 for the ribbed tire and 44.5 to 32.8 for the smooth tire. In the right lane, friction numbers averaged 46.7 to 38.3 for the ribbed tire and 43.7 to 29.7 for the smooth tire. The friction numbers did not meet Pennsylvania Department of Transportation guidance for additional investigation or action because the roadway surface had sufficient friction:

[39] The temporary lines were part of the resurfacing project completed in September 2019. The temporary markings were replaced with permanent white lines in September 2020, according to the Pennsylvania Turnpike Commission.

[40] ASTM was formerly known as the American Society for Testing and Materials. Standards for ribbed testing tires are established in ASTM E501-08 (2020), "Standard Specification for Standard Rib Tire for Pavement Skid-Resistance Tests." Standards for smooth testing tires are established in ASTM E524-08 (2020), "Standard Specification for Standard Smooth Tire for Pavement Skid-Resistance Tests." The roadway friction values were gathered immediately after the crash; the NTSB used these values in the friction test.

[41] ASTM E-274 is titled "Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire." The skid friction tester was manufactured by International Cybernetics Corporation in 2012.

Actions should be recommended for those sections that meet ribbed tire test results that yield skid numbers of 35 or less; or smooth tire test results that yield skid numbers of 20 or less.[42]

Lane Marking Conspicuity (Reflectivity). After the crash, the Pennsylvania Turnpike Commission, at the NTSB's request, contracted with an engineering firm to test the reflectivity of the westbound highway lane markings near the crash site. The purpose was to verify the conspicuity of the markings under conditions similar to those at the time of the crash. Wet and dry retroreflectivity tests that measured the luminous intensity of the markings were performed on January 23, 2020.[43] The results showed that the lane markings were in excellent condition.

1.7.3 Road Treatment

According to information from the Pennsylvania Turnpike Commission, a truck from the Donegal maintenance facility on the Pennsylvania Turnpike near the crash site made four passes on January 4 and 5 to apply salt to the westbound roadway between mileposts 88.8 and 83.5.[44] Passes near milepost 86.1 were made at 11:48 p.m. on January 4 and at 1:48 a.m., 2:20 a.m., and 3:20 a.m. on January 5. The truck alternated between the left and right lanes. It applied 450 pounds of salt per mile on the pass just before midnight on January 4 and 300 pounds per mile during the three passes early on January 5. The maintenance truck drivers told the NTSB that they did not encounter any black ice or slippery conditions on the turnpike.[45]

Pennsylvania Turnpike Commission procedures for snow and ice removal call for removing snow when it falls at a minimum rate of half an inch per hour. A 0.25-inch ice accumulation would also require action. From 6:00 p.m. on January 4 to 4:00 a.m. on January 5, a remote weather station at milepost 99.65 on the turnpike recorded slight precipitation, accumulating at a rate of between 0.24 and 0.21 inches per 24 hours, which is below the rate requiring removal.[46]

1.7.4 Traffic

According to the Pennsylvania Turnpike Commission, average daily traffic volumes in 2019 on the Pennsylvania Turnpike near the crash site totaled

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[42] Pennsylvania Department of Transportation, *District Highway Safety Guidance Manual*, section 5.6.18, "Wet Pavement Crashes," May 2019.

[43] The test method was ASTM-E-1710, "Standard Test Method for Measurement of Retroreflective Pavement Marking Material with CEN-Prescribed Geometry Using a Portable Retroreflectometer."

[44] Mileposts on the Pennsylvania Turnpike are numbered from west to east.

[45] The National Weather Service defines *black ice* as patchy ice on roadways or other transportation surfaces that cannot easily be seen. The ice is usually transparent (not white), allowing the black road surface to show through.

[46] The precipitation accumulation in inches per 24 hours is a rolling average.

17,965 vehicles westbound and 19,382 vehicles eastbound. At the NTSB's request, the Pennsylvania Turnpike Commission performed a 24-hour (midnight-to-midnight) vehicle classification count near the crash site on March 1, 2020. A Sunday was chosen because that was the day the crash occurred. The study results are shown in table 3.

Table 3. Westbound vehicles recorded at milepost 86.1, Pennsylvania Turnpike, March 1, 2020.

Vehicle Type	Count	Percent
Cars	12,315	73.5
Motorcycles	2	0.0
Four-tire single-unit trucks	1,938	11.6
Buses	45	0.3
Single-unit trucks	228	1.3
Single-trailer trucks	2,081	12.4
Multitrailer trucks	148	0.9
Total	16,757	100.0

During the 5 years before the crash, three accidents occurred on the curve at the crash site. On July 18, 2014, a piece of debris struck a vehicle traveling west, causing minor damage. On October 31, 2015, a vehicle's left front tire blew out, and the driver lost control. On June 23, 2019, a vehicle's right front undercarriage hit a boulder on the roadway.

1.7.5 Signage

Over the 4 miles preceding the crash site, the westbound Pennsylvania Turnpike was marked with a series of 38 regulatory and warning signs that were consistent with the Federal Highway Administration (FHWA) *Manual on Uniform Traffic Control Devices*. The signs indicated speed limits (advisory and regulatory), descending hills, upcoming curves, medians or shoulders (marked by chevrons), and road hazards such as fallen rocks.

Beginning at 10:00 p.m. on January 4 (5.5 hours before the crash), a series of five dynamic message signs (large, electronic signs that overhang or are placed alongside highways) were displayed along the westbound Pennsylvania Turnpike in advance of the crash location (between mileposts 163.0 and 92.7). The signs read "Winter weather conditions" and "Use caution"; they did not indicate a speed. The nearest dynamic message sign to the crash site was 6.6 miles east (at milepost 92.7).

1.7.6 Speed Limits

Including its mainline and all extensions, the Pennsylvania Turnpike contains 150 horizontal curves (covering about 51 miles) that have posted advisory speeds of 55 mph, 60 mph, and 65 mph.[47] An advisory speed is a recommended safe speed for all vehicles operating on a section of highway, based on highway design (number of lanes, width of median, horizontal and vertical alignment), operating characteristics (vehicle speeds), and conditions. An advisory speed sign is required when the difference between the regulatory and the advisory speeds is more than 10 mph, as on the curve where the crash occurred. Advisory speeds are not enforceable.

The turnpike has about 1,054 miles of roadway where the posted regulatory speed limit is 70 mph. The regulatory speed limit is the maximum (or minimum) speed applicable to a section of highway, as established by law or regulation, and is therefore enforceable. The original speed limit of 70 mph had been lowered over the years but was reestablished at 70 mph in May 2016. The NTSB requested a crash study of the Pennsylvania Turnpike before and after the 70-mph regulatory speed limit took effect.[48] The study showed that after May 2016, the average 5-year crash rate increased from 1.28 crashes to 1.64 crashes per 100 million vehicle miles traveled.

The Pennsylvania Turnpike Commission assessed the safety of the horizontal curves before raising the speed limit to 70 mph—specifically, whether the design speed of the curves was less than the proposed speed limit. Design speed is a selected speed used to determine the geometric design features of a roadway. It is generally understood as the maximum speed that passenger vehicles can travel based on driver comfort, given the centrifugal forces acting on a vehicle in a curve.[49]

The commission's assessment focused on approaches used by other states, elements used to assess horizontal curve locations, and crash clusters pertaining to speed and heavy vehicle congestion.[50] The design speed for the horizontal curve

[47] Curves that change the alignment or direction of a road are known as *horizontal curves*. Curves that change the grade or slope of a road (as on a hill) are known as *vertical curves*.

[48] See *Preliminary Report 70 MPH Speed Limit Study*, prepared by URS for Pennsylvania Turnpike Commission (March 4, 2014).

[49] According to AASHTO, the selected design speed should be a logical one with respect to the anticipated operating speed, topography, the adjacent land use, modal mix, and the functional classification of the roadway. Design speed does not take into account traffic flow nor weather conditions. (AASHTO 2018)

[50] A *crash cluster* was defined as a location that had seven or more crashes in 3 years. Some states used methods such as design speeds as criteria for increasing speeds. Many states relied on crash data to identify problematic sites. Some states evaluated interchange design, spacing, and congestion. No states considered truck/car speed differential. The Pennsylvania Turnpike Commission factors in the 85th percentile speed to set speed limits, as recommended by FHWA. The 85th percentile speed is the speed at which 85 percent of the traffic is traveling at or below.

preceding the crash location was computed as 62 mph, using a formula that considered curve radius, superelevation rate, and side friction demand. As a result of the assessment, the turnpike commission installed curve warning signs, advisory speed signs, and chevron signs at the horizontal curve preceding the crash location and at all curves where the design speed was less than the proposed 70-mph speed limit.

1.7.7 Speed Study

To assess how the speeds of the crash vehicles compared with normal speeds on the Pennsylvania Turnpike, the NTSB asked the Pennsylvania Turnpike Commission to perform a speed study. The turnpike commission performed such a study on April 8–21 and May 11–13, 2021, at the horizontal curve near milepost 86.1 and at two other left-hand horizontal curves on the westbound turnpike (at mileposts 82.9 and 95.7) that had similar radiuses, superelevations, advisory speeds, and numbers of chevron signs on the highway shoulders. The tests were conducted between 8:00 a.m. and 2:00 p.m., under two conditions:

- *Condition 1*: Motorists were advised about an ongoing speed study by a portable message sign ("Advisory Speed 55 MPH / Active Speed Study") positioned about 1 mile before each curve, with a Pennsylvania State Police car stationed 1 to 5 miles before the curve (car's lights not activated).

- *Condition 2*: Motorists were not advised about the speed study.

The results (see table 4) showed that the 85th percentile speeds at all three locations were 10 to 25 mph above the advisory speed (55 mph) and 0 to 18 mph above the design speed (62 mph at milepost 86.1 and 65 mph at mileposts 82.9 and 95.7).[51] Each data set contained motorcycles, cars, buses, and trucks. Buses traveled the slowest under both conditions, followed by trucks towing trailers under condition 1.

[51] In a typical speed study, the results are grouped into "bins" consisting of a range of speeds (for example, 65 to 70 mph), as in table 4.

Table 4. Results of speed study on westbound Pennsylvania Turnpike.

Category	85th Percentile Speed (mph)		
	Milepost 86.1	Milepost 82.9	Milepost 95.7
Condition 1: Motorists Informed			
All vehicles	70–75	65–70	70–75
Cars	70–75	65–70	70–75
Buses	65–70	70–75	(a)
Single-unit trucks	70–75	65–70	65–70
Single-trailer trucks	65–70	65–70	65–70
Multitrailer trucks	65–70	65–70	65–70
Condition 2: Motorists Not Informed			
All vehicles	70–75	70–75	70–75
Cars	75–80	75–80	75–80
Buses	65–70	70–75	65–70
Single-unit trucks	70–75	70–75	70–75
Single-trailer trucks	70–75	70–75	70–75
Multitrailer trucks	70–75	70–75	65–70

[a] Only 1 bus was counted, traveling 65–70 mph.

In 2017, the NTSB issued a safety study, titled *Reducing Speeding-Related Crashes Involving Passenger Vehicles*, which found that the *Manual on Uniform Traffic Control Devices* guidance for setting speed limits in speed zones is based on the 85th percentile speed, but there is not strong evidence that, within a given traffic flow, the 85th percentile speed equates to the speed with the lowest crash involvement rate on all road types (NTSB 2017). The study also found that unintended consequences of the reliance on using the 85th percentile speed for changing speed limits in speed zones include higher operating speeds and new, higher 85th percentile speeds in the speed zones, and an increase in operating speeds outside the speed zones. Further, the safety study found that expert systems such as USLIMITS2 can improve the setting of speed limits by allowing traffic engineers to systematically incorporate crash statistics and other factors in addition to the 85th percentile speed, and to validate their engineering studies. The NTSB issued Safety Recommendation H-17-27 to the FHWA to address these issues:

> Revise Section 2B.13 of the *Manual on Uniform Traffic Control Devices* so that the factors currently listed as optional for all engineering studies are required, require that an expert system such as USLIMITS2 be used

as a validation tool, and remove the guidance that speed limits in speed zones should be within 5 mph of the 85th percentile speed.

Safety Recommendation H-17-27 is classified "Open—Acceptable Response."[52] (Also see section 2.4.5 of this report for further discussion about the FHWA's use of 85th percentile speed.)

1.8 Crash Reconstruction

1.8.1 Site Documentation

The crash events occurred about 200 feet east of milepost 86.1 on the Pennsylvania Turnpike. Before the crash scene was cleared, Pennsylvania State Police investigators documented the site by means of small unmanned aircraft system (sUAS) aerial photography, three-dimensional laser scanning, and total station mapping.[53] In addition, the NTSB documented the site using photography and an sUAS.[54] The Pennsylvania Turnpike Commission hired a contractor to corroborate the vertical grade and cross-slope of the pavement and the lower part of the embankment bordering the right side of the highway. The contractor confirmed that the vertical grade of the westbound approach to the crash area descended about 3 percent.

1.8.2 Data Sources

All four commercial vehicles involved in the crash were powered by engines manufactured by Detroit Diesel Corporation and electronically managed by various ECMs. This section describes the data that were available to the NTSB postcrash; the next section (1.8.3) describes the data and the events that led up to the crash.

The two UPS trucks were outfitted with tractor telemetry units (TTUs) that transmitted, via cellular signals, vehicle location (latitude and longitude), time, speed, and ignition status, as well as harsh-brake events, defined as a minimum decrease in

[52] See also the NTSB's response to the FHWA's notice of proposed amendments to the manual, docket no. FHWA-2020-0001 Regulations.gov.

[53] An sUAS is defined at 14 *CFR* Part 107. A *total station* is an electronic/optical instrument that measures vertical and horizontal angles and the slope distance from the instrument to a point; it includes a computer to collect data and perform calculations.

[54] The NTSB produced 3D point clouds (plots of individual points in three-dimensional space) using sUAS aerial photographs and total station data.

vehicle speed of 10 mph per second.[55] UPS sent hardcopy data from the TTUs to the NTSB.

As described earlier, each of the three truck-tractor semitrailer combination vehicles was equipped with a Detroit Assurance safety system. Segments of the recordings from the FedEx truck's video event recorder system illustrated the operation of the truck leading to the impact with the overturned motorcoach, including where the motorcoach passed the truck before the collision.[56]

Engine parametric and event data were accessible through two commercially available, Detroit Diesel-authorized software packages—DDEC Reports and Diagnostic Link. DDEC Reports produced data related to last-stop, hard-braking, and fault code events. Last-stop and hard-brake records were reported as time-series events. The records could contain up to two hard-brake events, one last-stop event, and three most-recent fault-code events.[57]

A last stop typically occurs when vehicle speed slows to 1.5 mph or below, followed by an ignition "off" or the vehicle remaining stopped for at least 15 seconds.[58] Last-stop data cover 104 seconds before and 15 seconds after an event. A hard-brake event typically triggers when a decrease in speed over time exceeds a programmed threshold. For the vehicles involved in the crash, the threshold was a decrease in speed of 7 mph per second. Time-series data for a hard-brake event were reported at 1-second intervals over a period of 60 seconds before and 15 seconds after the trigger threshold.

The Pennsylvania State Police recovered the ECM from the motorcoach. It was transferred to the NTSB for transport to Detroit Diesel headquarters in Michigan, where it was examined and downloaded on February 19, 2020. Detroit Diesel technicians furnished data from DDEC Reports and Diagnostic Link to the NTSB. Pennsylvania State Police investigators downloaded the ECMs in the FedEx truck and

[55] (a) The unit manufacturer was CalAmp Corporation. CalAmp advised the NTSB that the module could accommodate more than 100 parameters and that all settings would be user defined. UPS could provide few details about how the units were integrated in its vehicles. (b) A harsh-brake event in TTU data is essentially the same as a hard-brake event in ECM data.

[56] As noted earlier, the video cameras in the Lytx DriveCam system were not part of the FedEx truck's Detroit Assurance system.

[57] Event time and date are based on an internal clock (typically formatted as eastern daylight time), which, if not updated, will lose accuracy (drift) over time. To adjust for drift, the event time/date is adjusted to that of the computer during data download. Accuracy of the time/date stamp relies on both the internal system clock and the computer. Event time accuracy after adjustment can be further influenced by an irregular time drift and the accuracy of the initial setting.

[58] The DDEC-V ECM in the motorcoach could require 20–25 seconds to write a last-stop record.

the two UPS trucks on January 16, 2020.[59] The ECMs were accessed while still in the vehicles, using the DDEC Reports software.

1.8.3 Details of Crash Events

The NTSB examined electronic data from the commercial vehicles involved in the crash, vehicle damage, roadway evidence (scarring and friction marks), and photographic and video evidence to determine details of the crash sequence, including vehicle speeds at various points. The occupants of the passenger car declined to be interviewed; the speed of their vehicle is unknown.

Motorcoach. ECM data show that the motorcoach entered the curve preceding the crash site at 77 mph (see table 5). Sixteen seconds before the ECM recorded a last stop, the driver briefly applied the service brakes (for about 6 seconds), which reduced the motorcoach's speed to 70 mph. As the motorcoach continued around the curve and down the grade, maintaining the roadway heading, its speed steadily decreased, with no indication that the driver depressed the service brake pedal. The engine throttle stayed at 0 percent. As noted earlier, the motorcoach was equipped with an engine brake. The ECM did not record the status of the engine brake, but the brake would not engage if the driver stepped on the accelerator and activated the throttle.

Table 5. Final 17 seconds of motorcoach ECM data.

Time from Last Stop Event (sec)	Vehicle Speed (mph)	Engine Speed (rpm)	Brakes On	Engine Load (%)	Throttle (%)	Calculated Longitudinal Acceleration (*g*)	Motorcoach Action
17	77.0	1728	No	0	0	--	Enters curve
16	76.0	1707	**Yes**	0	0	-0.046	
15	75.0	1685	**Yes**	0	0	-0.046	
14	74.0	1660	**Yes**	0	0	-0.046	
13	72.5	1631	**Yes**	0	0	-0.068	
12	71.5	1609	**Yes**	0	0	-0.046	
11	70.5	1589	**Yes**	0	0	-0.046	
10	70.5	1585	**Yes**	0	0	0.000	
9	70.0	1578	No	0	0	-0.023	
8	69.5	1560	No	0	0	-0.023	
7	67.0	1508	No	0	0	-0.114	

[59] Although the three trucks had different engine models, all were managed by a DDEC 16 ECM.

6	62.5	1401	No	0	0	-0.205	
5	57.5	1284	No	0	0	-0.228	
4	61.5	1393	No	0	0	0.182	
3	60.0	1342	No	15.5	38.8	-0.068	
2	24.5	687	**Yes**	90	100	-1.619	
1	9.0	607	**Yes**	90.5	71.6	-0.707	
0	15.5	188	No	100	54.4	0.296	Last stop

NOTE: Acceleration was calculated by the NTSB. It represents the rate at which the motorcoach was slowing over each 1-second interval (feet per second per second). Acceleration is negative when a vehicle is slowing (deceleration). Data between 3 and 0 seconds from the last stop event are associated with the motorcoach's initial impact with the embankment, its rotation, and its rear impact with the embankment.

The average speed of the motorcoach during the last 1 minute 41 seconds before it crashed was 73.8 mph, with a maximum speed of 80 mph. About 460 feet before the motorcoach left the road, the data reflect a speed loss equivalent to a deceleration of 0.114 *g* (shown at 7 seconds in table 6), with no recorded braking or throttle application. Seconds before the motorcoach left the road, its speed increased to 61.5 mph, again with no indication of throttle application.

The motorcoach left the highway 302 feet from the end of the curve and hit the embankment abutting the right shoulder about 3 seconds before the last-stop event. The impact occurred 195 feet west of the end of the concrete barrier that paralleled the right shoulder. The motorcoach's recorded speed at impact was 60 mph. Soil disruption and furrowing on the embankment indicated that the motorcoach departed the pavement at an angle of about 32°. The embankment sloped 38° and consisted mostly of grass covering a substrate of rocky aggregate, with numerous large rocks that the motorcoach exposed or displaced. The steep embankment angle and firm, rocky terrain, coupled with the vehicle's angular heading, resulted in substantial impact damage to the right front of the motorcoach.

After the right side of the motorcoach struck the embankment, it rotated clockwise 166°. While the motorcoach rotated, its rear bumper scraped the road surface and left a white, arced mark on the pavement. The motorcoach then rode up the embankment, as evidenced by soil disruption 68 feet west of where it left the roadway. The ascent onto the embankment damaged the left rear of the motorcoach and caused the engine to stall with soil debris. The engine stall coincided with the last-stop event recorded by the ECM at 3:29:02 a.m. (0 seconds in table 5).[60] The ECM did not record a hard-brake event.

After striking the embankment, the motorcoach overturned onto its right side (rolled 90°) and slid across the pavement, while continuing to rotate, until the front

[60] Comparison with the time display on the video in the FedEx truck suggests that the last-stop event occurred about 1 minute and 48 or 49 seconds earlier than indicated by the ECM record.

end struck and dislodged a 12-foot-long segment of the median barrier. The motorcoach came to rest approximately perpendicular to the travel lanes, with its undercarriage facing east (refer to figure 3 in section 1.1).[61] The motorcoach's initial position of rest was 162 feet west of the point where it departed the roadway (see figure 17).[62]

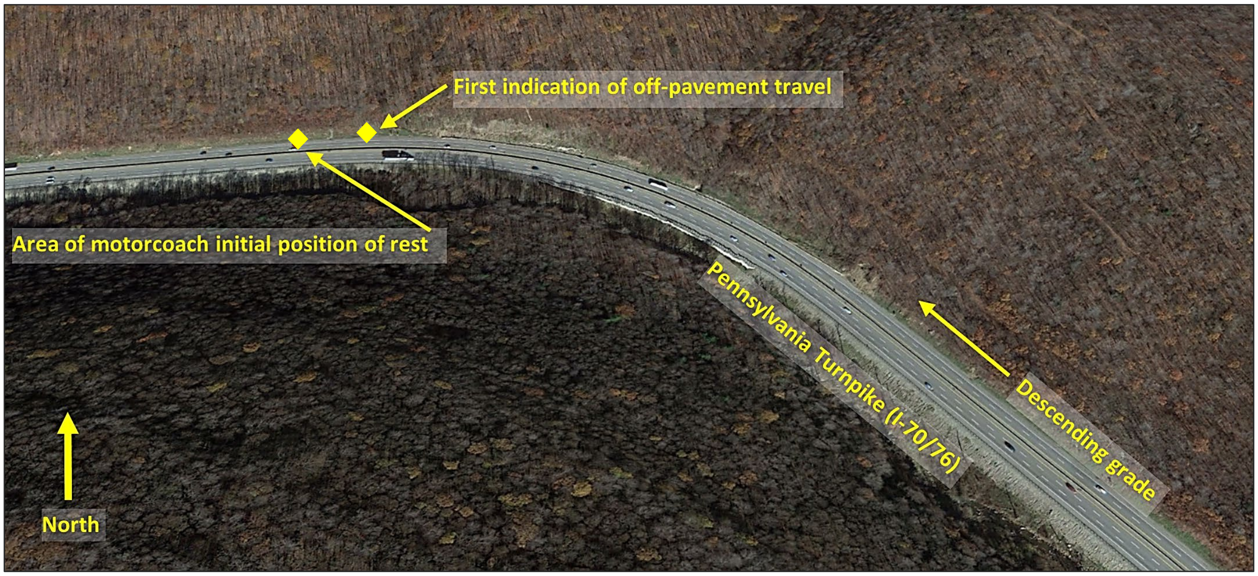

Figure 17. Motorcoach departure point from pavement and initial position of rest. (Source: Google Earth image with NTSB overlay)

The motorcoach's entry door and one of two windshield panels were found near the base of the embankment, 35 and 64 feet west, respectively, of the roadway departure point. The first windshield panel was at the pavement's edge; the second was 21 feet up the embankment. The location of the door and windshield panels indicates that they were displaced when the motorcoach hit the embankment. Based on its initial position of rest, the motorcoach's center of gravity was redirected an estimated 58 feet farther west by the impacts with the trucks, which also caused it to rotate clockwise an additional 90°.

From the physical evidence, it could not be determined in which lane the motorcoach had been traveling before it left the highway. No motorists in other vehicles witnessed the motorcoach's roadway departure, crash, and rollover. However, when interviewed by the NTSB, a passenger seated behind the driver said that he was "about to doze off" when "something" made him open his eyes and he saw "the bus drifting over to the yellow line that is a border for the opposite side of the road" (referring to the line separating the travel lane from the median shoulder).

[61] (a) The motorcoach rotated a total of about 240° from its original direction of travel. (b) Retroreflective tape is not required on the undercarriage of vehicles.

[62] The motorcoach's approximate center of gravity was used to measure the distance.

He said that “the passengers started to scream,” and the driver “was frightened because he was dozing off.” The driver then made a “wide swing to the right,” and the bus turned over. Another passenger (seated about five rows back) said that she looked out the front window when she felt the motorcoach do “something strange” and saw that it was not pointing forward but toward something on the left, which it hit. A passenger (seated two rows from the back) said that the bus swerved multiple times to the left and right and then rolled over. A passenger seated near the front said that the bus swerved hard (left, then right) and hit something before it rolled over. A passenger seated in the row in front of the restroom also said that the motorcoach swerved before it crashed. Three passengers stated that the driver was driving fast. The investigation found no evidence of an impact to the motorcoach before it struck the embankment.

FedEx Truck. Based on the time the motorcoach passed the FedEx truck, the FedEx truck’s speed, and ECM data from the motorcoach, the FedEx truck crashed into the motorcoach less than 25 seconds after the motorcoach had settled into a stable position after rolling over. The motorcoach passed the FedEx truck about 5,400 feet from the crash location, according to evidence from the truck’s video cameras and friction marks on the road. Integrating the times from the video and the ECM records, about 53 seconds elapsed between the motorcoach passing the FedEx truck and the motorcoach’s last-stop event. The truck’s ECM recorded the collision as a last-stop and hard-brake event at 3:32:37 a.m.[63]

The ECM data indicate an overall average speed for the FedEx truck of 48.7 mph during the last 96 seconds before the crash, with a maximum speed of 54 mph. The truck’s speed as it entered the curve preceding the crash location was 53 mph, then dropped to a steady 51.5 mph until the hard-brake event. The data indicate that the FedEx driver began braking 266 to 304 feet, or 5.1 to 5.3 seconds, before impact. The recording from the truck’s inward-facing video camera shows the driver sitting upright, then grabbing the steering wheel and turning it slightly to the left before the truck hits the motorcoach. The DriveCam parametric data also indicate that the driver applied braking. The ECM hard-brake event was triggered 1 second after the brake was applied.[64] Based on the DriveCam data and video from the FedEx truck, the estimated speed at which the FedEx truck struck the motorcoach was about 21 mph.

Using data from the NTSB’s sUAS photogrammetry, the NTSB evaluated the possible obstruction to the FedEx driver’s view of the motorcoach created by the highway curve and the median barrier. A limitation on the line of sight for objects

[63] The time could not be validated because the ECM clock was in the instrument cluster and could not be accessed. The overall data appeared to be consistent with the crash events, but the time stamp lagged the time recorded by the video system by 1 minute 20 seconds.

[64] The data indicate an average deceleration of 0.29 *g*.

below the height of the median barrier, considering also the curve, was estimated at 600 feet.[65] Illumination from the FedEx truck's headlights would have fallen below the height of the barrier. The 600-foot line-of-sight would have been increased, however, by the roadway's grade and by the driver's sitting position above the barrier's height.

UPS-1. Within 2 seconds (according to ECM and video data) of the FedEx truck coming to rest after colliding with the motorcoach, UPS-1, traveling in the left lane, crashed into the right rear of the FedEx trailer. A tire mark in the left travel lane was consistent with the path of UPS-1. The sequence of events after UPS-1 crashed was determined from the initial and final positions of the vehicles as well as the damage evidence.

In the video from the FedEx truck, the motorcoach was lying perpendicular to the travel lanes. At the end of the crash sequence, the motorcoach was lying parallel to the travel lanes and was entangled with the FedEx truck. Given the low speed of the FedEx truck, the motorcoach's position would not have changed much after the collision by the truck. However, the weight and impact speed of UPS-1 were sufficient to push the FedEx truck forward, causing the motorcoach to rotate 90° clockwise and move farther west. The final rest positions of the trucks and the type and severity of the damage are consistent with UPS-1 having pushed the FedEx truck against the median barrier, displacing the fifth-wheel coupler on the FedEx tractor and separating the semitrailer. The front of the FedEx trailer came to rest on top of the median barrier. The right front of the FedEx tractor came to rest against the undercarriage of the motorcoach, mainly blocking the left lane.

The front of UPS-1 sustained catastrophic damage when it struck the FedEx trailer. The UPS-1 trailer intruded into the cab's sleeper berth and came to rest at an angle of 124° relative to the tractor (jackknife). The damage and postcollision position are consistent with the UPS-1 driver steering right just before UPS-1's left side hit the FedEx trailer.

Pennsylvania State Police investigators recovered no hard-brake or last-stop data from UPS-1's ECM that related to the crash.[66] UPS provided a printout of vehicle position and speed data received through the vehicle's onboard TTU. Vehicle position was conveyed as global navigation satellite system (GNSS) latitude and

[65] The sightline evaluation was not intended to represent stopping sight distance as used for highway design. For this crash, the major limiting factor was illumination. For design purposes, at 70 mph, the American Association of State Highway and Transportation Officials (AASHTO) recommends a stopping sight distance of 771 feet on a 3-percent downgrade (AASHTO 2018). The design standard includes a perception-response time of 2.5 seconds. AASHTO defines *sight distance* as "the distance along a roadway throughout which an object of specified height is continuously visible to the driver."

[66] A sudden or catastrophic engine shutdown or electrical failure resulting from the collision could have precluded the writing of data to the ECM memory.

longitude.[67] The TTU data indicate continuous operation of the vehicle, with an average reported speed of 67 mph during the last 2 hours before the crash. UPS-1 entered the curve preceding the crash location at 71 mph.

At 3:31:18 a.m., the TTU data for UPS-1 show a sudden drop in speed from 71 to 0 mph. One second later, the reported speed was 56 mph. The location coordinates where the truck's speed suddenly dropped are just east of the crash site; the subsequent coordinates approximate the area of impact and UPS-1's final rest position. According to UPS representatives, the 1-second sampling interval and zero speed value could indicate a harsh-brake event, which is equivalent to a deceleration of about 0.45 *g*. Typically, a harsh-brake event would be accompanied by the transmission of additional data, including vehicle speed, position (latitude and longitude), and brake indication, at 1-second intervals. No such data were received.

At the time the FedEx driver began braking, the TTU position data showed that UPS-1 trailed his vehicle by 612 feet in the left lane. As the FedEx driver began moving into the left lane, UPS-1 was 541 feet behind him. At that point, the difference in speed between the two trucks was 23 mph (71 mph for UPS-1, 48 mph for the FedEx truck). The speed differential increased as the FedEx driver began braking. By the time the FedEx truck had slowed to 33 mph, UPS-1 was 440 feet behind it, with a speed differential of 38 mph. When the FedEx truck hit the motorcoach, 335 feet separated UPS-1 from it. The speed differential between the trucks at impact could not be determined, because it is unknown when the UPS-1 driver began braking (which the sudden drop in recorded speed noted above indicates that he did). The speed at which UPS-1 struck the FedEx truck could not be established from the available data, but the last recorded speed of UPS-1 was 56 mph.

UPS-2. The UPS-2 driver told the NTSB that along the route preceding the crash, he would pass UPS-1 on ascending grades, while UPS-1 would pass him on descending grades. As the two UPS vehicles approached the crash curve, UPS-1 was 3 to 4 seconds ahead of UPS-2, based on TTU data for time, position, and speed. Their separation might have increased to 5 seconds by the time UPS-1 collided with the FedEx truck, considering that UPS-1 was ahead of UPS-2 and traveling faster downhill.

The TTU data indicate that UPS-2's average speed for the last 2.5 hours before the crash was 66 mph, and that it entered the curve preceding the crash site at 69 mph. The truck's ECM recorded a hard-brake event and a last-stop event at, respectively, 3:31:50 a.m. and 3:31:58 a.m. on January 5, after adjusting for ECM clock drift. TTU data suggest that those times might lag the actual time by about 30 seconds.

[67] The global positioning system (GPS) includes satellites in the GNSS.

The TTU data for UPS-2 did not indicate a harsh-braking event and continued to log the truck's speed and position until 3:31:24 a.m., when its speed decreased from 67 to 0 mph. The GNSS coordinates placed the vehicle less than 1,000 feet from its final rest position. The data sample 10 seconds later reported 0 mph, and the GNSS position approximated the vehicle's position of final rest against the embankment. As UPS-2 departed the roadway onto the right-side embankment, it sideswiped the passenger car and then slid back down the embankment, pushing the passenger car against UPS-1.

1.9 Motor Carriers

1.9.1 Z&D Tour

Z&D Tour, Inc., was registered with the FMCSA as a for-hire motor carrier on June 6, 2012, with its principal place of business in Rockaway, New Jersey. The company's latest registration document (MCS-150, dated November 11, 2019) listed it as having eight motorcoaches.[68]

The company offered motorcoach service from New York City to Cincinnati, Ohio, and Louisville, Kentucky. Runs were generally scheduled every day, depending on demand. Motorcoaches normally ran twice a day from New York City, leaving for Louisville at 9:00 p.m. and Cincinnati at 10:00 p.m. Motorcoaches also ran from Cincinnati and Louisville to New York City daily. The company ceased operation in November 2020.

Safety Practices. The company's policy manual included a section on driver safety and accident prevention that discussed using caution during inclement weather, the dangers of excessive speed, and operation around curves. Drivers were required to review and sign the manual when they were hired. They were not required to repeat the review during their employment. The manual stated the following about driving in winter weather:[69]

> Good traction is necessary for starting, stopping and maneuvering safely. On snow, ice or cold wet roads, your tires can spin easily if you accelerate too hard. And they'll lock easily when you brake too hard.

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

[69] State CDL driver manuals provide specific guidance for driving in inclement weather. For example, the manual for California, where the motorcoach driver obtained his CDL, states: "Wet roads can double stopping distance. You must drive slower to be able to stop in the same distance as on a dry road. Reduce speed by about 1/3 (for example, slow from 55 to about 35 mph) on a wet road" (*California Commercial Driver Handbook*, p. 2-16). The FMCSA publishes similar guidance on its web-based informational platform, "CMV Driving Tips: Too Fast for Conditions."

> On snow or ice-covered roads, the objective is to slow the wheels down, rather than stopping them from turning at all—which is what will happen when the brakes are locked. Locked brakes often will cause skidding. If you skid, turn the steering wheel in the direction of the skid, until the commercial motor vehicle straightens out. To prevent skidding, apply your brakes gently, or tap them "on and off, on and off." Don't follow vehicles too closely. Reduce your speed.

The manual stated the following about rounding curves:

> When approaching a curve the speed should be decreased and the brakes applied. A slight acceleration on the curve helps to overcome the centrifugal force that tends to push the vehicle out of its proper lane.

Z&D did not have a documented fatigue management program. The company scheduled driving shifts that usually lasted less than 8 hours and provided lodging where off-duty drivers could rest.

Compliance Reviews. In 2010, the FMCSA established the Compliance, Safety, and Accountability system to improve the safety of large trucks and buses. The system quantifies a carrier's performance in seven Behavior Analysis and Safety Improvement Categories (BASICs)—unsafe driving, hours-of-service compliance, driver fitness, controlled substances and alcohol, vehicle maintenance, hazardous materials compliance, and crash indicator.[70] Z&D had been subject to a new entrant audit under the system in December 2013. Z&D had also undergone two FMCSA comprehensive compliance reviews and a nonrated (focused) compliance review.[71] The comprehensive compliance reviews (held on April 14, 2016 and November 12, 2018) were rated satisfactory. The nonrated review took place on August 28, 2013. At the time of the crash, Z&D had no BASIC alerts.

[70] Carriers are placed in percentiles, with 100 signifying the worst performance. Thresholds are set for interventions such as warning letters or investigations. An alert is posted on a carrier's profile if it exceeds the threshold for any BASIC. Thresholds are set at different BASIC percentiles depending on vehicle type. For example, the intervention threshold for passenger carriers in the unsafe driving, crash indicator, and hours-of-service category is 50 percent, whereas the general threshold is 65 percent. As noted on the FMCSA's BASICs website, "the BASICS with stronger association to future crash involvement have lower intervention thresholds than the other BASICs."

[71] A comprehensive compliance review applies when three or more BASICs have exceeded their thresholds and may be used if the carrier was involved in a crash or there has been a complaint about the carrier's operation. The review addresses all aspects of a company's operation and normally results in a safety rating, which the FMCSA determines according to the methods outlined at 49 *CFR* 385.5. A safety rating can be satisfactory, conditional, or unsatisfactory, as prescribed at 49 *CFR* 385.7.

Postcrash, the FMCSA conducted a comprehensive compliance review (January 6 to February 7, 2020). Multiple violations were noted, including the following:

- Hours of service:
  - Making false report of duty status—drivers were logging time as bus passengers as off-duty; regulations state that status is on-duty, not-driving time (not crash driver).
  - Logging fueling time as driving time (not crash driver).
- Failing to enter commodity or bill of lading number (crash driver).
- Vehicle inspection reports:
  - Failing to require driver to prepare vehicle inspection reports.
  - Failing to complete post-trip inspection report (not crash driver).

The FMCSA did not assess a civil penalty for the violations, and Z&D received a satisfactory safety rating. As part of the postcrash review, the FMCSA verified that Z&D was not operating under an out-of-service order or as a subsidiary of a carrier that was under an out-of-service order. The FMCSA also determined that Z&D was not a reincarnated carrier.[72]

Maintenance and Inspection. Z&D had its routine vehicle maintenance performed by Golden Bus Service Center in Brooklyn, New York. The semiannual inspections required by the state of New Jersey were performed by Vision Tours in Jersey City, New Jersey. The New Jersey Motor Vehicle Commission conducts annual inspections on all commercial buses and motorcoaches registered in the state. Z&D underwent 12 roadside inspections by New Jersey State Police between March 28, 2018, and June 4, 2019. The out-of-service rate for the inspections was zero for both drivers and vehicles, compared with a nationwide average of 5.5 percent for drivers and 20.7 percent for vehicles.[73]

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[72] When a motor carrier reestablishes the company under another name, with a new DOT number or new location in an attempt to avoid FMCSA oversight, it is referred to as a *reincarnated* carrier (49 *CFR* 386.73).

[73] A carrier or commercial driver can be placed out of service for violating certain conditions. The Commercial Vehicle Safety Alliance establishes out-of-service criteria. The finding of an out-of-service condition by a qualified inspector precludes further operation by the driver or of the vehicle until the condition is corrected.

1.9.2 FedEx

FedEx Ground Package System, Inc., was registered with the FMCSA as a for-hire motor carrier on October 25, 1985, with a primary place of business in Moon Township, Pennsylvania. At the time of the crash, the carrier's MCS-150 form listed 4 owned vehicles and 63,330 trailers, with leases on another 66,480 vehicles and 91,085 drivers operating under its authority. As noted earlier, FedEx leased the truck involved in the crash from Sioux Trucking in Santa Rosa Valley, California. A contractual agreement between Sioux and FedEx detailed their respective responsibilities.

Safety Practices. Sioux had extensive written policies and procedures as well as a written agreement with FedEx that incorporated FedEx policies and procedures. Written safety rules required truck occupants to wear seat belts and to use the restraint system (net webbing) in the sleeper berth. The rules prohibited speeding, cell phone use while driving, and driver distraction.[74] The driver involved in the crash had completed the required training.

FedEx's contract with Sioux required leased trucks to be equipped with an ELD and a video event data recorder (with forward- and cab-facing cameras). The contract also required trucks to be equipped with a forward collision warning system and a speed limiter set to 65 mph.

Compliance Reviews. Sioux was not required to be a registered DOT carrier and therefore was not subject to FMCSA compliance reviews.[75] FedEx had undergone 11 nonrated and 5 rated FMCSA compliance reviews since 1987. The rated results were all satisfactory.[76] The FMCSA did not conduct a compliance review on FedEx after the crash but assigned a safety investigator to review the carrier's practices. The FMCSA also reviewed the FedEx driver's regulatory compliance (hours of service, medical certification, postcrash drug and alcohol testing, ELD verification).

[74] Sioux's fleet policy states in its driver safety rules: "Do not engage in distracting activities while driving. This includes using a cell phone for talking or texting, eating, using a computer, GPS or MP3 player, applying makeup, reading, looking at maps, or any other activity that takes a person's eyes or attention away from driving. Drinking non-alcoholic beverages is acceptable." Sioux's employee handbook states: "Employees who drive on Company business must abide by all state or local laws prohibiting or limiting portable device . . . use, including cell phones or personal digital assistants, while driving. Further, even if use is permitted, employees must choose to refrain from using any [portable device] while driving unless using a hands free device. 'Use' includes, but is not limited to, talking or listening to another person or sending an electronic or text message via the [portable device]."

[75] Sioux was not required to be registered as a DOT carrier because the company was contracted solely to operate under FedEx's authority.

[76] The reviews were in August 1987, April 1991, May 1993, February 1994, and March 1996.

No issues were identified. At the time of the crash, FedEx had BASIC alerts for hours of service and driver fitness, none of which applied to the crash driver.

Maintenance and Inspection. Maintenance records provided by the carrier were compliant with the *FMCSR*s. According to its profile in the FMCSA database, FedEx vehicles underwent 13,448 roadside inspections in the 24 months before the crash. The out-of-service rate was 1.9 percent for drivers and 13.7 percent for vehicles, compared with a national rate of 5.5 percent for drivers and 20.7 percent for vehicles.

1.9.3 UPS

United Parcel Service of America was registered as a for-hire motor carrier with the FMCSA on June 1, 1974, with a primary place of business in Atlanta, Georgia. According to its most recent MCS-150 form (dated September 26, 2019), at the time of the crash, UPS owned 98,785 straight trucks, 27,164 truck-tractors, and 96,285 trailers; it employed 118,498 drivers.[77] Leased vehicles were not listed on the form. UPS operated two of the trucks involved in the crash, UPS-1 and UPS-2. Both were leased from Penske Truck Leasing, headquartered in Reading, Pennsylvania.[78]

Safety Practices. Most of the UPS truck fleet was speed-governed at 68 mph. UPS operated a few trucks governed at 72 mph, the use of which required special approval. Sleeper units were governed at 70 mph. Both trucks involved in the crash had sleeper berths and therefore were governed at 70 mph. UPS provided annual training to its drivers about adjusting speed under different road, weather, and traffic conditions. UPS required leased trucks to be equipped with forward collision avoidance systems.[79]

Compliance Reviews. At the time of the crash, UPS had received 25 nonrated and 2 rated compliance reviews since 1990. Both rated reviews (on May 8, 1990, and July 22, 1999) were satisfactory. UPS had no BASIC alerts at the time of the crash.

Maintenance and Inspection. According to both UPS and Penske representatives, the lease contract stipulated that vehicle repairs would be performed by Penske, except for repairs necessitated by a collision or driver abuse. If a UPS driver discovered a defect or other issue, the driver would fill out a driver vehicle

[77] On *straight trucks*, all axles are attached to a single frame.

[78] The company is a joint venture of Penske Corporation, Penske Automotive Group, and Misui & Co.

[79] Penske has required forward collision avoidance systems on its fleet since 2017, according to its vice president of maintenance. Daimler refers to its Detroit Assurance system as a collision *mitigation* system. The NTSB uses the term collision *avoidance* system. The functionality of the systems overlaps; for example, AEB can lessen (mitigate) the severity of a crash or avoid it entirely.

inspection report (DVIR) and contact Penske directly.[80] Penske would send a service truck to the UPS hub or have the driver take the truck to the Penske facility if it was safe to do so. If the vehicle repair was expected to take a long time, a substitute vehicle would be assigned. Penske did not send paperwork to UPS describing work performed or items that needed repairing. The Penske maintenance technician would clip a summary of the work that had been done onto the driver's sun visor in the truck.

UPS vehicles underwent 14,322 roadside inspections in the 24 months before the crash. The out-of-service rate was 1.0 percent for drivers and 7.6 percent for vehicles, compared with a national rate of 5.5 percent for drivers and 20.7 percent for vehicles.

1.10 Weather

No weather advisories or warnings were in effect for Westmoreland County at the time of the crash, according to the National Weather Service hazardous weather outlook issued at 3:54 a.m. on January 5. The near-surface temperature at the crash site was 28°F near the time of the crash, with lake-effect snow (off Lake Erie) and light, freezing drizzle. A remote weather station 13.6 miles east of the crash site reported snow accumulating at an average of 0.21 inches per 24 hours. As noted earlier, 6.6 miles east of the crash site, messages reading "Winter weather conditions" and "Use caution" were displayed beginning 5.5 hours before the crash.

The sky was dark at the time of the crash. According to data from the US Naval Observatory, both the sun and the moon were more than 15° below the horizon, providing no illumination.

1.11 Simulation Study

The NTSB conducted a series of simulations using the TruckSim® software and speed data from the motorcoach's ECM.[81] The study focused on identifying the dynamics that would have caused the slowing and variations in speed recorded

[80] Motor carriers, including passenger-carrying vehicles, are required by 49 *CFR* 396.11 to have drivers prepare written reports at the completion of each day's work about each vehicle operated, listing "any defect or deficiency that could affect the vehicle's safe operation or result in its mechanical breakdown." The regulation does not further define defects or deficiencies, but it requires that the DVIRs cover at least a vehicle's brakes, steering mechanism, lights and reflectors, tires, horn, windshield wipers, rearview mirrors, coupling devices, wheels and rims, and emergency equipment. DVIRs must be submitted to the motor carrier so that repairs can be made. Since 2014, DVIRs are no longer required for property-carrying vehicles at the end of each day if there are no defects or deficiencies to report. In 2020, the FMCSA amended 49 *CFR* 396.11 to also rescind the requirement that drivers of passenger carriers submit a DVIR when no defect or deficiency is discovered. Both printed and electronic versions of DVIRs are acceptable.

[81] The software is a product of Mechanical Simulation Corporation. See the NTSB public docket (case number HWY20MH002) for further information about the simulation study.

between 10 and 3 seconds before the motorcoach's engine shut off. As shown in figure 18, ECM data indicate that the driver did not engage the service brakes or the throttle during that time.

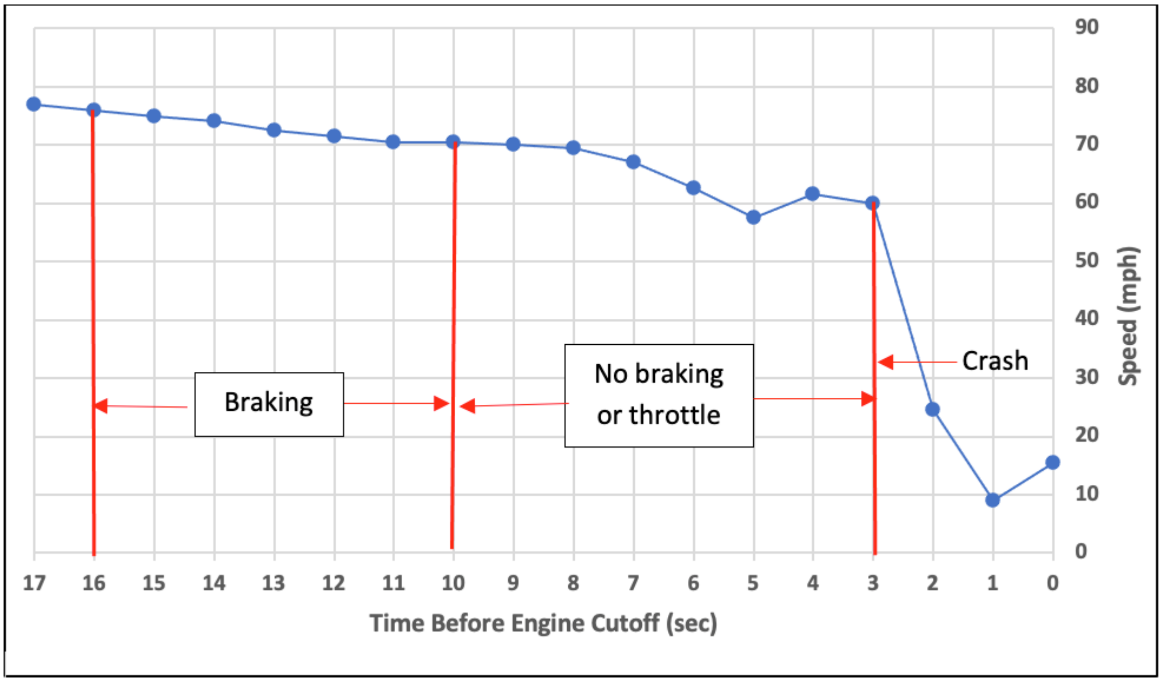

Figure 18. Speed data from motorcoach's ECM.

The simulations examined (1) driver steering, (2) use of the engine brake, and (3) road grade as possible explanations for the speed readings. Simulations were conducted both with and without the engine brake engaged.[82] The study used tire data to examine the effects of vehicle speed and wet pavement on the traction available to the motorcoach on the curve.[83] The data supported that the motorcoach would have had sufficient traction to safely negotiate the curve on wet pavement. The ECM data could not be modeled without the engine brake engaged.

The simulations produced speed readings similar to the ECM readings by engaging the engine brake in the curve and applying sharp, back-and-forth steering. The back-and-forth steering resulted in "fishtailing," which occurs when a vehicle's rear tires begin to lose traction and the driver countersteers in an attempt to stabilize the vehicle. It could not be determined whether the sharp, back-and-forth steering

[82] See section 1.6.1 for a description of the engine brake.

[83] Data came from tests on motorcoach tires conducted as part of a previous NTSB investigation and the results of friction tests carried out on the crash curve in July 2021 (see section 1.7.2).The previous investigation was of a 2003 crash in Hewitt, Texas (NTSB 2005). For details on the tire tests, search the NTSB public docket for NTSB accident number HWY03MH022 and refer to the Vehicle Dynamics and Simulations study.

might have occurred in response to the motorcoach's tires sliding on the wet pavement, or whether it could have resulted from the driver's attempts to maneuver the bus in the curve.

A motorcoach has a high center of gravity, and the driver's seat is several feet forward of the center of gravity. Those characteristics could have made it more difficult to control the motorcoach on wet pavement at high speeds than to control a car under the same conditions, because a high center of gravity makes motorcoaches more prone to rolling over than cars, and drivers seated forward of the center of gravity are less likely to feel a loss of traction in the rear tires.

Based on the tire data, reducing the motorcoach's speed to the 55-mph advisory speed limit before it entered the curve would have increased the available traction, in addition to reducing the friction required to safely negotiate the curve (known as friction demand). The increase in traction along with the reduction in friction demand might have enhanced the motorcoach driver's ability to maintain control, according to the study.

1.12 Postcrash Actions

1.12.1 Pennsylvania Turnpike Commission

Curves-Ahead Signs. The curve preceding the crash site did not qualify as a high-crash location.[84] Nevertheless, after the crash, in May 2021, the Pennsylvania Turnpike Commission installed curves-ahead signs on the turnpike at mileposts 99.7 and 88.9 westbound and milepost 121.8 eastbound. The signs contained flashing beacons to warn motorists to reduce their speed, particularly at night, near horizontal curves. The signs were 14 feet wide and 15 feet high and were powered by underground electrical conduits or solar panels.

Curve Warning Projects. At the time of this report, the Pennsylvania Turnpike Commission was researching ways to warn motorists of upcoming curves through FM radio and connected vehicle technology. An experimental system at one eastbound exit ramp used the Radiolert® product in combination with video and radar vehicle sensors to broadcast short "Slow down, curve ahead" warnings over FM radio.

The commission was also establishing a laboratory for testing connected and automated vehicle technology, particularly the potential for integrating the

[84] In 2014, a study of curve warning systems for the Pennsylvania Turnpike Commission determined that the turnpike had 11 horizontal curves that had a radius of curvature of ≤ 1,432 feet (4°) and an average of four or more crashes per year along the curve. Mitigation efforts reduced the crash rates at most of the locations. Mitigation efforts included installing chevron alignment signs (signs that delineate the alignment of the road around a curve), surface treatments on bridges, supplemental pavement markings, and curve warning signs.

technology with the turnpike's curve speed warning system. A project to apply road-weather-connected vehicle technology to one section of the Pennsylvania Turnpike near Harrisburg, known as the Harrisburg Connected Road project, was in the planning stages.[85] The project will focus on safety, weather, incident management, and work-zone Traveler Information Message applications.

1.12.2 Penske

The Penske vice president of maintenance told the NTSB that since the crash, Penske had made numerous changes to its maintenance procedures. One is that Penske began placing vehicles out of service if they had faults in their collision avoidance or AEB systems. In May 2020, Penske began a pilot program, called Proactive Solutions. Under the program, Penske notified lessors if an issue was discovered with a vehicle's collision avoidance/AEB system. The lessor could override Penske's default decision of placing the vehicle out of service until the fault was corrected. The notification system was operational as of August 2020. By the time of this report, over 6,300 notifications had been sent to lessors, and no lessors had overridden a Penske decision.

1.12.3 United Parcel Service

UPS told the NTSB postcrash that it had updated its checkride program, a training evaluation tool used to train drivers to examine their vehicles for defects and repair issues during pre- and post-trip checks. The updated program now requires drivers to check the external sensors for the AEB system as well as the fault warning lights for the AEB system on the dashboard.

[85] Road weather applications employ sensors that activate intelligent transportation systems along roadways and disseminate information to travelers. The technology is envisioned as being able to "detect and forecast road weather and pavement conditions." For more information, see the DOT's intelligent transportation system website, "Road Weather Connected Vehicle Applications" (accessed July 7, 2021).

2. Analysis

2.1 Introduction

The crash sequence began as the motorcoach was descending a 3-percent slope and traveling through a left curve; the motorcoach driver made a sharp steering input to the right, causing a loss of control. The sharp rightward steer caused the motorcoach to veer from the travel lanes, run off the right side of the road, strike the embankment beside the road, rotate and strike the embankment again with its rear, and then overturn, blocking all westbound travel lanes and shoulders. Within seconds, the motorcoach was struck by a FedEx truck. Shortly thereafter, a UPS truck impacted the crashed vehicles. A car and a second UPS truck that were following on the turnpike avoided crashing into the other vehicles by veering right, where they came to rest wedged side by side against each other. Two motorcoach passengers, the motorcoach driver, and the UPS-1 driver and codriver died; 49 passengers received minor-to-serious injuries. The FedEx codriver also sustained minor injuries. The FedEx driver, the UPS-2 driver and codriver, and the occupants of the car were not injured.

This analysis first discusses factors that could be excluded as not causing the crash or contributing to the severity of its outcome, as well as the emergency response to the crash. It then addresses the possible role of fatigue in the motorcoach driver's actions (section 2.2), the speed of the vehicles involved in the crash, including the motorcoach loss of control (section 2.3), and the collision avoidance systems on the vehicles (section 2.4). The crash investigation identified the following safety issues:

- Excessive speed for wet road conditions for the motorcoach and the two UPS trucks (section 2.3).
- Lack of standards for commercial vehicle collision avoidance and mitigation systems to enhance safety (section 2.4).
- Lack of onboard video event recorder systems on commercial motor vehicles (section 2.5).

The NTSB established that the following did not cause or contribute to the crash:

- **Qualifications of the motorcoach driver:** The driver held a CDL, which included an endorsement for transporting passengers, with no restrictions. His medical certification was current.

- **Use of alcohol or other drugs by the motorcoach driver:** Toxicological tests were performed on blood samples obtained during the motorcoach driver's autopsy. The results were negative for alcohol and other drugs.

- **Cell phone use by the motorcoach driver:** The driver's cell phone records showed that he was not using a cell phone before the crash.

- **Mechanical condition of the motorcoach:** Postcrash inspection of the motorcoach found no mechanical defects in the steering gear. No damage was visible in the suspension system, and no defects were found in the brakes. The transmission was intact, and the drive axle housing was undamaged. All the tires were found inflated after the crash, with tread depths above the regulatory minimums.

- **Pavement condition:** The roadway at the crash location was resurfaced in 2019 and met friction specifications in tests conducted after the crash. Conspicuity (reflectivity) tests conducted after the crash showed that the lane markings near the crash site were in excellent condition. A system of grates drained water away from the roadway, and the shoulder beside the roadside embankment on the right was sloped to direct water away from the travel lanes. Both shoulders in the westbound direction were equipped with rumble strips to warn drivers if they departed from the travel lanes.

- **Road treatment strategies:** The Pennsylvania Turnpike Commission's remote weather station near the crash site reported light precipitation at the time of the crash, with snow accumulating at a rate of 0.20–0.24 inches per 24 hours. Although that rate of snowfall did not meet the thresholds in the commission's guidance for treating the road during storms, the commission proactively applied salt to the turnpike in the hours before the crash. Salt-dispersion trucks made a pass near the crash site just 10 minutes before the crash. Although temperatures near the crash site were below 32°F, forward-facing video from the FedEx truck showed no snow accumulation on the roadway and that the road had a wet surface.

The NTSB concludes that none of the following were factors in the crash: (1) qualifications of the motorcoach driver, (2) use of alcohol or other drugs by the motorcoach driver, (3) cell phone use by the motorcoach driver, (4) mechanical condition of the motorcoach, (5) pavement condition , and (6) roadway salt treatment used to address the freezing conditions.

The circumstances of the crash presented challenges to emergency responders. It involved multiple commercial motor vehicles, one of which was a motorcoach loaded with passengers, and a high number of injuries and fatalities. It also required the dispatch and response of mutual aid from numerous fire and emergency medical services in conditions of inclement weather and darkness. The dispatching of resources was appropriate, and the emergency response from the Pennsylvania State Police, fire departments, and public and private emergency medical services was effective. The extrication and transportation of the injured was as expeditious as possible under the prevailing conditions. The NTSB therefore concludes that the emergency response to the crash, including transportation of the injured, was timely and effective.

2.2 Assessment of Motorcoach Driver Fatigue

The NTSB considered whether driver fatigue might have played a role in the motorcoach's departure from the roadway. Data used in the assessment included witness statements, roadway evidence, ECM data, and the motorcoach driver's work schedule and cell phone records. Roadway evidence and information about the motorcoach driver's off-duty activities in the days before the crash were limited, however.

Passengers gave varied information about the motorcoach driver's actions before the vehicle departed the roadway. One passenger, who was seated directly behind the driver, told the NTSB in an interview that he (the passenger) was about to doze off when something made him open his eyes. He said that he saw the motorcoach drifting over to the yellow line—the line between the left lane and the median barrier dividing the two directions of traffic on the turnpike.[86] Then, he reported that other passengers screamed, which appeared to frighten the driver, who had been "dozing off." The passenger said that the driver then made a "wide swing to the right" before the motorcoach hit the embankment. Three passengers seated in the middle and back of the motorcoach told the NTSB that the motorcoach driver was driving too fast during the trip.[87] The passengers also gave various accounts of swerving (left then right; left, right, left, then right) or loss of vehicle control before the impact with the embankment.

According to research, in a typical fatigue-related event, the vehicle departs the roadway gradually, most likely off the right side in this roadway configuration, at an angle of about 3° (Lisper, Laurell, and van Loon 1986). The passenger seated directly behind the motorcoach driver stated that he saw the bus drift to the left, which could still indicate a case of an inattentive, drowsy driver allowing the vehicle to drift toward the median and making a sharp overcorrection when startled to

[86] See the motorcoach interview transcript (Human Performance attachment) in the public docket for this investigation.

[87] See the motorcoach passenger interviews (Survival Factors attachment) in the public docket for this investigation.

alertness. The other passenger accounts could indicate a loss of control before the driver made a sharp steering input.[88]

The NTSB reviewed the motorcoach driver's work schedule and cell phone records to identify opportunities for him to sleep in the days before the crash. The schedule consisted of a dedicated route from and to the carrier's base in Queens, New York, and a driver exchange point in New Stanton, Pennsylvania. The motorcoach driver was familiar with the route and roadway. Each segment of the trip comprised a single shift of 6 or 7 hours. The start times of consecutive shifts rotated; that is, a shift that began in the evening and ended in the early morning was followed by a shift that began—after a 24-hour break for the driver—in the early morning and ended in the late morning. Then, after a 12-hour break for the driver, the cycle would begin again with an evening-to-early morning shift.[89] (For more information, refer to figure 6 in section 1.5.1.)

Fatigue is generally caused by a lack of adequate sleep, which can be influenced by circadian rhythms, waking hours, quality of sleep, and medical conditions.[90] The crash occurred at 3:30 a.m., during a time of night when, based on circadian rhythms, fatigue is likely to occur (Van Dongen and Dinges 2005). The NTSB has previously issued safety recommendations pertaining to circadian rhythm and fatigue, such as Safety Recommendation H-12-30 to the FMCSA, following a 2011 motorcoach crash in Doswell, Virginia:

> Incorporate scientifically based fatigue mitigation strategies into the hours-of-service regulations for passenger-carrying drivers who operate during the nighttime window of circadian low.
>
> Safety Recommendation H-12-30 is classified "Open—Unacceptable Response."

The motorcoach driver in the Mt. Pleasant Township crash was working a rapidly rotating shift schedule, defined as a schedule that rotates every 3 days or more often. Research has found that rapidly rotating shifts are "associated with reduced total sleep duration" for workers compared with the sleep of workers on

[88] No roadway evidence was available to corroborate the passenger statements (the physical evidence began at the motorcoach's impact with the embankment).

[89] FMCSA hours-of-service rules for motorcoach drivers are promulgated at 49 *CFR* 395.

[90] Circadian rhythms are 24-hour cycles that constitute the body's internal clock, running in the background to carry out essential functions and processes. One of the most important circadian rhythms is the sleep–wake cycle. When circadian rhythms are disrupted—such as when a person is working a nighttime schedule—it can negatively affect biological activities, including brain function, linked to the 24-hour cycle.

slower rotating shifts.[91] Therefore, even though the motorcoach driver was given breaks between shifts to obtain adequate sleep and was provided with a place to rest when his shift ended in Pennsylvania, the fact that the shifts were rapidly rotating might have reduced the duration and quality of his sleep.[92]

Based on his on-duty times and cell phone usage, 3 days before the crash (January 2), the driver had 10 hours 45 minutes of sleep opportunity during the daytime. Two days before the crash (January 3), he had 18 hours 38 minutes of sleep opportunity during the daytime. One day before the crash (January 4), the driver had 10 hours 25 minutes of sleep opportunity during the daytime. However, the motorcoach driver's off-duty activities during his sleep opportunities in the days leading to the crash could not be reconstructed from the available information. Therefore, the NTSB concludes that although the motorcoach driver had adequate opportunities for sleep in the days before the crash, when and how long he slept and the quality of any sleep he had could not be determined.

The NTSB considered medical or physical conditions that can affect the quality and quantity of sleep and that might have contributed to fatigue on the part of the motorcoach driver, such as sleep disorders. Obstructive sleep apnea is a disease in which patients experience episodes of airway obstruction while sleeping, resulting in fragmented sleep, daytime sleepiness, and fatigue. The motorcoach driver was overweight (with a recorded BMI of 28.7 kg/m^2), which can increase the risk of obstructive sleep apnea (Schwartz and others 2008).[93] However, the driver had not been diagnosed with any sleep disorders. Also, in a postcrash interview with the NTSB, the motorcoach driver's wife stated that he generally slept well and did not have difficulty falling or remaining asleep. Given this information, it is unlikely that the driver had a sleep disorder such as obstructive sleep apnea.

Finally, the NTSB examined the driver's actions in the moments before the crash. The passengers reported that the driver refueled the motorcoach about 15 minutes before the crash, giving him a break from the driving task. In addition, as depicted in the FedEx forward-facing video, about 50 seconds before the motorcoach crashed, the driver was following the road heading. According to ECM data, the driver applied the service brakes at the onset of the curve. Those actions indicate that the motorcoach driver was alert enough to respond to the high speed at which he entered the curve.

[91] A 2000 meta-analysis examined the effects of different types of shifts on shift worker sleep lengths (Pilcher, Lambert, and Huffcutt 2000).

[92] The carrier provided a place of rest for the driver in New Stanton, Pennsylvania.

[93] The Schwartz report states that 40 to 90 percent of individuals with BMIs over 40 kg/m^2 have moderate-to-severe obstructive sleep apnea. The driver's BMI was well below that benchmark.

ECM data further show that about 14 seconds after he entered the curve, the motorcoach stopped abruptly. That is when the motorcoach impacted the right roadside embankment. Based on the scarring of the embankment, the motorcoach had turned sharply at a 32° angle. The impact angle required a sudden, sharp steering input to the right. Although the passenger seated behind the driver interpreted the driver's steering input as a result of a startle from "dozing off," the driver could also have been steering to control the swerving action of the motorcoach, as reported by other passengers.

In summary, the NTSB identified factors suggesting that fatigue could have played a role in the crash, including time of day, driver's rotating work schedule, passenger interview reports, and possible drifting out of the travel lanes. However, some of the evidence does not support fatigue, including that the motorcoach driver had adequate opportunities for sleep (although the quality and quantity of his sleep are unknown), that he took a break from the driving task 15 minutes before the crash (during a stop for fuel, lasting about 25 minutes), that he applied the service brakes at the onset of the curve, and that his sharp steering input could have been a reaction to losing traction in the curve. In consideration of all available information, the NTSB therefore concludes that the evidence is insufficient to establish that fatigue was a factor in the crash.

2.3 Vehicle Speed

This section analyzes speed data for the motorcoach and the three trucks involved in the crash (the occupants of the car declined to be interviewed and their vehicle speed is unknown). The discussion refers to the regulatory speed limit, the advisory speed for the curve, and considerations for traveling speed on wet roads. The regulatory speed limit is the speed applicable to a section of highway as established by law and is therefore enforceable. In this case, the enforceable speed limit on the Pennsylvania Turnpike was set to 70 mph. An advisory speed is a recommended safe speed for vehicles operating on a particular section of a highway and is based on highway design, operating characteristics, and conditions. An advisory speed sign is required when the difference between the regulatory and the advisory speeds is more than 10 mph, as on the curve where the crash occurred. Advisory speeds are not enforceable. The advisory speed limit for the curve was set to 55 mph.

The FHWA encourages agencies to use two expert systems tools in establishing appropriate speed limits for all road users, USLIMITS2 and the National

Cooperative Highway Research Program (NCHRP) 966.[94] One of the input variables used in both tools is the 85th percentile speed, which is the speed at which 85 percent of the vehicle traffic is traveling either at or below. Research has shown that the 85th percentile speed is an outdated form of obtaining speed study results (NTSB 2017). It has been in use since the 1940s and has shown undesirable results, such as motorists driving faster than the posted speed. State DOTs and turnpike authorities, including the Pennsylvania Turnpike Commission, have used the 85th percentile speed in establishing speed limits on interstates where vehicles and vulnerable road users mix. It is imperative that the tools available on the FHWA's website that agencies are encouraged to use to set appropriate speed limits for all road users de-emphasize the use of the 85th percentile speed. The NTSB therefore concludes that the 85th percentile speed used in the FHWA's tools, USLIMITS2 and NCHRP 966, to set appropriate speed limits on all roadways is outdated and should be de-emphasized. The NTSB therefore recommends that the FHWA evaluate the applicability and use of the 85th percentile speed input variable in both of its tools, USLIMITS2 and NCHRP 966, for setting appropriate speed limits to reduce serious and fatal injuries.

Considerations for speed in wet road conditions are also discussed in this section of the report. The Pennsylvania Turnpike Commission installed dynamic message signs advising drivers to slow down for adverse weather conditions in the crash area. A vehicle traveling at a higher speed requires a longer stopping distance than at lower speeds, and the driver must respond to a hazard more quickly to avoid a collision (vehicle weight also affects the required stopping distance). Higher speeds also lead to larger differences between a vehicle's precrash and postcrash velocity, which, in turn, leads to greater injury severity in a crash.

2.3.1 Motorcoach

The ECM data show that the motorcoach entered the 55-mph advisory speed curve at 77 mph, 22 mph above the curve advisory speed limit, despite the wet roadway and nighttime conditions. The motorcoach's speed was 24 mph faster than the speed at which the FedEx truck entered the curve (53 mph).

The data show that after entering the curve, the driver applied the service brakes for 7 seconds, slowing the motorcoach to 70.5 mph. The motorcoach continued around the curve for the next 5 seconds, slowing to 57.5 mph without

[94] The USLIMITS2 and the NCHRP 966 are tools recommended by the FHWA to help practitioners set speed limits for specific segments of roads, except for school or construction zones. The USLIMITS2 uses operating speed (50th and 85th percentile), annual average daily traffic, roadway characteristics and geometric conditions, level of development in the area around the road, crash and injury rates, presence of on-street parking, and extent of pedestrian and bicyclist activity, depending on the road type. The NCHRP 966 uses minimum segment lengths by speed limit, upper and lower speed limits by group, crash rates, and speed limit groups.

additional service brake inputs by the driver on the downhill slope. The ECM did not record driver-applied throttle inputs after the motorcoach entered the curve. Despite the absence of throttle inputs, the motorcoach's speed increased to 61.5 mph, with a corresponding increase in engine speed, 1 second before the impact with the embankment on the right side of the road (which occurred about 3 seconds before the last-stop event).

The first physical evidence of the motorcoach's roadway departure relates to the impact with the embankment. No evidence was found to indicate the motorcoach's position before it departed the roadway or to show its motion on the road before the departure. The data from the motorcoach's ECM did not provide information on driver steering inputs. Calculations indicate that the motorcoach impacted the embankment at a 32° angle relative to the travel direction. One passenger statement indicated that the driver was startled and overcorrected with a sharp rightward steering input. Other passengers seated in the middle or rear of the bus recounted various swerving maneuvers or vehicle loss-of-control motions before the impact with the embankment.[95] Such motions would be similar to fishtailing.

Because of the lack of physical evidence before the motorcoach struck the embankment, the NTSB conducted a simulation to better understand possible vehicle dynamics through the curve. The simulation showed that the reduction in speed while the driver was not applying the service brakes was consistent with the engine brake being in the "on" position, increasing vehicle drag and thereby reducing the motorcoach's speed on the downhill grade. Without assuming an engaged engine brake, the simulation could not replicate the recorded reduction in motorcoach speed.[96] The NTSB concludes that the motorcoach's engine brake was likely engaged at the time of the crash when the driver released the service brake and the throttle.

Applying the engine brake slows a vehicle's drive wheels. On a wet roadway or slick surface, application of the engine brake could have decreased the traction in the rear of the motorcoach, thereby increasing the potential of wheel slip and sliding. If the driver responded with excessive steering inputs, it could have resulted in fishtailing. The simulation indicated that the motorcoach was most likely fishtailing before it hit the embankment at an angle of 32°, which would account for the recorded changes in speed immediately before the impact. In the simulation, driver steering inputs contributed to the fishtailing. The simulation could not determine

[95] As noted earlier, fishtailing occurs when a vehicle's rear tires begin to lose traction and the driver countersteers in an attempt to stabilize the vehicle.

[96] Activation of the engine brake was required in combination with a steering input for the simulation to replicate the changes in speed indicated in the engine ECM data.

whether driver steering inputs would have initiated the fishtailing motions or whether they would have been a response to a loss of control.

In the simulation, reducing the motorcoach speed to the 55-mph curve advisory speed provided greater tire traction and reduced the friction required to navigate the curve, which decreased the chances of fishtailing. Overall, the simulation showed that reducing the motorcoach's speed to the curve advisory speed would have resulted in increased vehicle control (a greater safety margin) for a high-center-of-gravity vehicle that was fully loaded and traveling on a wet roadway.

Z&D's policy manual stated that drivers should decrease their speed when approaching a curve. Further, the commercial driver handbook for California (the state where the motorcoach driver obtained his CDL) informs drivers, "Wet roads can double stopping distance. You must drive slower to be able to stop in the same distance as on a dry road. Reduce speed by about one-third (for example, slow from 55 to about 35 mph) on a wet road."[97] On this 70-mph-speed-limit roadway, a one-third reduction in speed would equate to 47 mph, which is about the speed the FedEx truck was traveling (46 mph) when the motorcoach passed it.

Although no physical evidence showed the position and motion of the fully loaded motorcoach before its impact with the embankment, the vehicle's high initial speed entering the curve, combined with the driver's likely use of the engine brake and his steering inputs on the wet roadway, would have reduced the available friction. The loss of available friction, combined with the driver's steering inputs, could have led to a loss of control, which then led to the roadway departure and impact with the embankment. The NTSB concludes that for unknown reasons, the motorcoach driver likely made excessive steering inputs beyond those needed to negotiate the curve. The NTSB further concludes that the motorcoach driver was traveling too fast for the wet roadway conditions, on a curve with the engine brake likely engaged, resulting in a loss of vehicle control that led to the roadway departure and impact with the right-side embankment.

Although the NTSB could not physically verify that the motorcoach's engine brake was switched on because of the extent of crash damage to the instrument panel, the simulation indicates that it likely was used because the motorcoach slowed on a downhill portion of the interstate without the service brakes being used. Using the engine brake is not recommended in low-friction-coefficient road conditions because it can make vehicle handling more difficult. The simulations conducted after the crash indicated that the motorcoach driver had probably turned on the engine brake before the crash, despite the wet road conditions.

[97] *California Commercial Driver Handbook*, p. 2-16. As noted earlier, the FMCSA publishes similar information as "Driving Tips" for commercial vehicle drivers on its website.

The NTSB previously investigated a crash that occurred in Cañon City, Colorado, on December 21, 1999, in which a motorcoach was traveling at 70 mph on a curve, and the driver initiated the crash sequence by inappropriately deciding to use the engine brake under icy conditions (NTSB 2002). The recommendations resulting from that investigation were as follows:[98]

To the FMCSA:

> Develop, in cooperation with the United Motorcoach Association and the American Bus Association, a booklet that educates motorcoach drivers on the different types of retarders and on their use during low-friction-coefficient road conditions. Then, distribute this information to motorcoach carriers and other interested parties. (H-02-33)

To the United Motorcoach Association and the American Bus Association:

> Work with the Federal Motor Carrier Safety Administration to develop a booklet that educates motorcoach drivers on the different types of retarders and on their use during low-friction-coefficient road conditions. Then, distribute this information to motorcoach carriers and other interested parties. (H-02-34)

Safety Recommendation H-02-33 to the FMCSA is classified "Closed—Acceptable Action" because, in March 2007, the FMCSA, in cooperation with the United Motorcoach Association, the American Bus Association, and the Commercial Vehicle Safety Alliance, completed development and began distribution of an educational booklet titled "Motorcoach Brake Systems and Safety Technologies" (publication FMCSA-ESO-07-01; FMCSA 2007). The FMCSA continued to provide this information on its website as of the date of this report.

Safety Recommendation H-02-24 is also classified "Closed—Acceptable Action," based on the two organizations' cooperation with the FMCSA in developing the booklet. Despite the FMCSA having made information available for understanding and properly handling a vehicle's engine brakes, Z&D did not include the FMCSA's guidance in its training materials, and it appears that the engine brake may have been engaged in this crash. The NTSB concludes that the motorcoach driver's likely use of the engine brake on the curve where the crash occurred reduced the available traction on the roadway. Z&D is no longer in operation, as of November 2020. The NTSB is concerned, however, that other motorcoach operators might also not have the FMCSA's information in their training material. Therefore, the NTSB recommends that the American Bus Association and the United Motorcoach Association inform their members about the circumstances of the Mt. Pleasant

[98] An *engine brake* is a type of vehicle retarder.

Township crash, the importance of drivers following the FMCSA's guidance on engine retarders, "Motorcoach Brake Systems and Safety Technologies," and the need to incorporate the guidance into their members' training and manuals.

2.3.2 FedEx Truck

The FedEx truck was traveling at 51 mph (below the curve advisory speed of 55 mph) when the driver saw an object in the roadway (the overturned motorcoach) lying across all travel lanes and shoulders. The driver began braking and steered the truck from the right lane into the left lane about 300 feet from the overturned motorcoach. The inward-facing video in his truck showed that the FedEx driver reacted quickly to an unknown and difficult-to-observe hazard.[99] Because the FedEx driver was operating below the advisory travel speed and made a prompt response, he was able to decrease the truck's speed to about 21 mph at impact.

The slower travel speed selected by the FedEx driver gave him better control and more effective speed reduction for his truck before impact. The motorcoach occupied both lanes and both shoulders ahead, so there was no room to avoid the collision. However, because of his slower speed, the FedEx driver had an opportunity to mitigate the severity of the crash. The NTSB concludes that because the FedEx truck was traveling at a reduced speed when the driver became aware of the overturned motorcoach, the driver had time to react by braking, thus mitigating the severity of the truck's impact with the motorcoach.

2.3.3 UPS-1

UPS-1 was traveling in the left lane about 70 mph (15 mph above the curve advisory speed) when the FedEx truck driver began braking and then steered into the left lane. At that time, UPS-1 was about 600 feet behind the FedEx truck, and some upper portions of the FedEx trailer might have been in the UPS-1 driver's line of sight. When the FedEx driver applied the brakes, the distance between the two vehicles decreased, such that UPS-1 was about 335 feet behind the FedEx truck when it first struck the motorcoach.

Both the UPS-1 telemetry data and the physical evidence indicate that the UPS-1 driver most likely applied his truck's brakes and executed a rightward evasive steering maneuver at some point, resulting in a recorded speed of 56 mph near the

[99] The inward-facing video showed that the driver was wearing headphones at the time of the crash, and in a postcrash interview, the driver stated that he was listening to music. Although it is illegal in Pennsylvania to drive while wearing headphones, no auditory alerts sounded in the FedEx truck cab, and the driver's performance was not negatively affected.

time of impact.[100] The high impact speed at which UPS-1 collided with the FedEx truck resulted in catastrophic intrusion damage to the UPS-1 cab and subsequent impacts with the overturned motorcoach. The severity of UPS-1's impact with the back of the FedEx truck was sufficient to push the FedEx truck forward into the median barrier, causing separation of the FedEx truck and trailer, and pushing and rotating the motorcoach 90° clockwise and farther west.

Although, because of the crash damage, their seat belt status and use of the sleeper berth restraint system are unknown for the two UPS-1 occupants, the cab's survival space was lost as a result of the high-speed impact. In addition, the speed at which UPS-1 struck the at-rest FedEx truck and the overturned motorcoach increased the forces on the vehicles and most likely contributed to the injuries of the motorcoach occupants. Therefore, the NTSB concludes that although the driver of UPS-1 attempted to avoid the impact with the rear of the FedEx truck, UPS-1's initial speed was too fast for the wet roadway conditions and made the driver's braking attempts ineffective in substantially reducing his vehicle's speed before the impact, contributing to the severity of the injuries sustained by the motorcoach passengers and the UPS-1 drivers.

2.3.4 UPS-2

UPS-2 had been traveling in the right lane, according to the driver's statement, before encountering the crashed vehicles ahead. About 1,000 feet before UPS-2's final position of rest, its speed was 67 to 68 mph. The rear lights from both UPS-1 and the FedEx truck would have been visible before the crash, which might have helped the UPS-2 driver detect the hazard and react. The driver applied braking (the UPS-2 ECM recorded a hard-brake event) and brought the vehicle to a stop quickly enough that it caused only minor damage when it struck the passenger car that was also stopped on the right shoulder. UPS-2 did not hit any of the other vehicles, including the overturned motorcoach. The NTSB concludes that the UPS-2 driver most likely had cues to the slowing and crashed vehicles ahead, enabling him to reduce the truck's speed, steer to the right, and therefore inflict only minor damage to the car stopped alongside UPS-1.

2.3.5 Speed Countermeasures

Scope of Speed Issue. Traveling too fast for the wet curve led to the motorcoach's loss of control and impact with the embankment. UPS-1's high speed at

[100] Investigators could recover only limited electronic data from UPS-1's ECM, most likely due to a power loss during collision. Although no event data (that is, hard-brake, last-stop, or trouble codes) were recovered, certain operational data for the date of the crash were recorded and found to be consistent with data acquired from UPS-1's TTU.

impact contributed to the severity of the injuries. Speed contributed both to the cause of the crash and to the severity of its outcome.

According to a NHTSA report, in 2019, there were 9,478 fatalities in crashes where at least one driver was speeding, 26 percent of total traffic fatalities for that year (NHTSA 2021). An FMCSA report to Congress on large truck crashes identified "loss of control/traveling too fast for conditions" as among the top critical factors resulting in truck crashes (FMCSA 2005). Of the 32,000 trucks estimated to have been involved in crashes, 22.9 percent were traveling too fast for conditions, according to the FMCSA report.[101]

The NTSB has a long history of investigating highway crashes involving speed (including the NTSB's first highway crash investigation, of an August 1967 crash in Joliet, Illinois). In addition, the 2017 safety study *Reducing Speeding-Related Crashes Involving Passenger Vehicles* (NTSB 2017) included several new safety recommendations to multiple recipients such as NHTSA, the Federal Highway Administration, the US DOT, and the Governors Highway Safety Association.[102] The safety study focused on passenger vehicles; however, the principles pertaining to reducing speed-related crashes apply to heavy vehicles as well. In addition, the NTSB's Most Wanted List of Transportation Safety Improvements has included speeding as a safety improvement since 2019 for both heavy vehicles (trucks, buses, and motorcoaches) and cars. Currently, the Most Wanted safety improvement, "Implement a Comprehensive Strategy to Eliminate Speeding-Related Crashes," includes NTSB recommendations for the implementation of countermeasures to eliminate speeding-related crashes.

The NTSB also advocates for a Safe System Approach that aims to eliminate fatal and serious injuries for all road users. The approach acknowledges that humans make mistakes that lead to traffic crashes and that the human body has a limited physical ability to tolerate crash forces. It further recognizes that road safety is a shared responsibility involving multiple stakeholders and that redundancy is essential so that if one part of the transportation system fails, road users are still protected.[103] Safe speed is one of the five elements of a Safe System Approach. The concept of safe speed addresses speed reduction initiatives to accommodate human injury tolerances by reducing impact forces, giving additional time for drivers to stop, and

[101] "Too fast for conditions" is coded if the driver's speed was related to the crash, as determined by law enforcement.

[102] The NTSB conducted 49 major highway investigations between 1967 and 2015 in which speeding or speed was found to be a safety issue or a causal or contributing factor.

[103] See the Safe System Approach (ntsb.gov).

by improving visibility.[104] With this approach in mind, this section describes infrastructure and vehicle technologies countermeasures aimed at reducing speed.

Variable Speed Limit Signs. Although all the required roadway signage was in place at the time of the crash, the Pennsylvania Turnpike Commission proactively placed dynamic message signs next to the roadway preceding the crash location displaying the messages "Winter weather conditions" and "Use caution." The signs did not legally require drivers to slow to a new speed limit.

Speed limit signs are used to inform drivers of the maximum acceptable and safe speed for normal travel conditions. However, conventional static speed limit signs do not account for less-than-ideal weather and therefore may not display an appropriate, reasonable, or safe speed limit under those conditions. The use of variable speed limit signs is considered an effective countermeasure to speeding because it can alert drivers who are traveling at speeds that are higher than appropriate for conditions (especially wet weather) by dynamically resetting the maximum regulatory speed, usually by using digital variable message signs. The FHWA has found that the use of the signs "during less than ideal conditions, such as heavy traffic and adverse weather, can improve safety by decreasing the risks associated with traveling at speeds that are higher than appropriate for the conditions and by reducing speed variance in traffic" (FHWA 2017). The FHWA has published a volume of case studies (Goodwin and Pisano 2003) on road weather management showing that variable speed limit signs have reduced vehicle speeds and crashes during inclement weather on, for example, the New Jersey Turnpike and on a busy mountain pass in Washington state. The speeds are set by the highway authority in response to changing roadway conditions and, because the speeds are regulatory rather than advisory, the limits are enforceable.

The NTSB investigated a 2003 crash in Hewitt, Texas, involving a motorcoach that was traveling in overcast weather with reduced visibility due to fog, haze, and heavy rain. The NTSB determined that the speed limit on the roadway exceeded the design speed and did not provide drivers with enough time to stop their vehicles (NTSB 2005). As a result of our investigation, we issued Safety Recommendation H-05-14 to the FHWA to "issue guidance recommending the use of variable speed limit signs in wet weather at locations where the operating speed exceeds the design speed and the stopping distance exceeds the available sight distance." In response to the recommendation, the FHWA issued a report on the use of variable speed limit systems in wet weather (FHWA 2012). The FHWA advised its division offices of the report's availability and held a webinar for the transportation community to advocate use of the report guidelines. As a result of those actions, the NTSB classified Safety Recommendation H-05-14 "Closed—Acceptable Action" in 2013.

[104] The system is further described at the Safe System Approach (dot.gov).

Although the Pennsylvania Turnpike Commission has yet to implement the use of variable speed limit signs, their use has been adopted by its close safety partner, the Pennsylvania Department of Transportation, an agency with which it has coordinated on shared visions for traffic safety.[105] As part of its efforts to improve traffic operations (including enhancing safety), in 2021, the Pennsylvania Department of Transportation completed installing intelligent transportation system devices along Interstate 76 from the Pennsylvania Turnpike in King of Prussia, Pennsylvania, to the US-1/City Avenue interchange in Philadelphia. The devices include 72 variable speed limit signs, 27 vehicle detectors, 9 dynamic message signs, and 1 closed-circuit television camera.[106] In its own efforts to improve safety, the Pennsylvania Turnpike Commission has installed flashing beacons and digital message signs on exit ramps to emphasize the presence of the ramps to motorists. In addition, the turnpike commission is exploring strategies to mitigate speed-related crashes, including curve speed warnings broadcast through an FM radio system, as well as connected vehicle applications. The beacons, signs, and broadcast messages are designed to direct the attention of drivers to the preexisting speed limits and advisory speeds on the turnpike. However, they do not address the need for motorists to reduce their speeds for variable and less-than-ideal conditions, such as wet or icy roads due to changing weather.

The NTSB concludes that had variable speed limit signs that change the regulatory speed limit and are enforceable, such as by speed safety cameras, been used to inform the drivers involved in the crash to slow to a speed more appropriate for a wet road surface, they would have been more likely to travel at lower speeds, which could have prevented or mitigated the crash. The NTSB therefore recommends that the Pennsylvania Turnpike Commission implement the use of variable speed limit signs or other similar technology to adjust statutory speeds based on real-time information regarding weather and road conditions.

Speed Safety Cameras. The effectiveness of variable speed limits can be improved with the use of automated enforcement, also known as speed safety cameras (FHWA 2017). Transportation agencies can use speed safety cameras to capture photographic or video evidence of vehicles that are traveling above a set speed threshold (FHWA 2021). Multiple studies have supported speed safety cameras as effective in slowing driver speeds and reducing speed-related crashes. According to an international study, the use of multiple cameras to capture average

[105] In 2017, the Pennsylvania Department of Transportation and the Pennsylvania Turnpike Commission, with other stakeholders, developed a Pennsylvania Strategic Highway Safety Plan, which outlined a comprehensive, data-driven strategy to reduce the number of traffic fatalities and injuries. Pennsylvania statute 212.108 allows the Pennsylvania Turnpike Commission to establish statutory speed limits in multiples of 5 mph up to the maximum lawful speed. It also allows the commission to change variable speed limits as a function of traffic speeds or densities, weather or roadway conditions, or other factors.

[106] The variable speed limit signs were placed about 215 miles east of the crash location.

speed over a certain distance (also known as point-to-point units) can reduce crashes on urban expressways, freeways, and principal arterials up to 37 percent for fatal and injury crashes (Montella, et al 2015). The study also reported that point-to-point units yielded crash reductions in rainy weather (57 percent), on wet pavement (51 percent), on curves (49 percent), and for single vehicle crashes (44 percent). As noted in the NTSB's 2017 *Reducing Speeding-Related Crashes Involving Passenger Vehicles* safety study, a review of 28 speed safety camera studies found that cameras reduced crashes 8–49 percent (NTSB 2017). The NTSB therefore concludes that speed safety cameras are an effective countermeasure to reduce speeding-related crashes, fatalities, and injuries.

The NTSB safety study included several safety recommendations aimed at reducing speed-related crashes, such as Safety Recommendation H-17-32 to the 28 states without automated speed enforcement laws:

> Authorize state and local agencies to use automated speed enforcement.

The overall status of Safety Recommendation H-17-32 is "Open—Unacceptable Response." However, Pennsylvania's status is "Open—Acceptable Response," because in 2018, the Pennsylvania General Assembly enacted legislation to permit automated speed enforcement in work zones. The NTSB supports this legislation and reiterates Safety Recommendation H-17-32 to Pennsylvania in this report. Currently, under Pennsylvania statute, speed safety cameras can be used only in active work zones given that certain conditions are met.[107] In March 2020, PennDOT and the Pennsylvania Turnpike Commission, in partnership with the Pennsylvania State Police, implemented a statewide program to reduce work zone speeds, change driver behavior, and improve work zone safety for workers and motorists. Despite the limited use of speed safety cameras in work zones, PennDOT and the Pennsylvania Turnpike Commission successfully captured 275,725 instances of speeding through construction zones.[108]

The benefit of using speed safety cameras could be extended to all portions of the Pennsylvania Turnpike; however, such actions would require the commonwealth

[107] Under Pennsylvania statute 75 Pa. C.S. § 3369 - Automated speed enforcement systems in active work zones: Speed safety cameras can be used in work zones only if: (1) At least two appropriate warning signs are conspicuously placed before the active work zone notifying the public that an automated speed enforcement device is in use. (2) At least one of the signs indicate if the automated speed enforcement system is active or not active. (3) An appropriate sign is conspicuously placed at the end of the active work zone. (4) A notice identifying the location of the automated speed enforcement system is posted at the active work zone and on the department's or Pennsylvania Turnpike Commission's publicly accessible Internet website. The notice on the websites shall remain throughout the period of use.

[108] Pennsylvania speed cameras: 1 in 4 drivers sped through work zones - The Morning Call (mcall.com).

of Pennsylvania to amend its statutes. The NTSB therefore recommends that the commonwealth of Pennsylvania seek authority to allow speed safety cameras to be used on the Pennsylvania Turnpike outside of active work zones.

Speed Limiters. In addition to infrastructure countermeasures, such as variable speed limit signs, vehicle-based solutions for speed exist. Electronic speed limiters are on-board vehicle technologies that govern or restrict a vehicle's operation to a maximum speed by limiting the engine's power. In the case of the Mt. Pleasant Township crash, all the commercial vehicles involved, except the motorcoach, were equipped with traditional electronic speed limiters that were engaged at the time of the crash. The speed limiters on the FedEx and UPS trucks were set to 65 mph and 70 mph, respectively.

The speed limiters on the three trucks involved in the crash were the traditional type. A newer technology, termed "advanced speed limiters" or "intelligent speed assistance systems," is a more active vehicle-based safety feature designed to keep a vehicle operating at safe speeds. Depending on the capabilities of the system, an advanced speed-limiting system can access information, including road/traffic signage (using a camera) and GPS system maps. A passive advanced speed-limiting application would alert the driver when the vehicle exceeds the speed limit (in the same way that smartphone-based navigation applications can alert a driver to speeds above the limit). An active advanced speed limiter adjusts a vehicle's speed in accordance with posted speed signs, either by requiring the use of greater force to the throttle when exceeding the speed limit (making speeding more physically demanding) or by automatically limiting the vehicle's speed.

Given the technical capabilities of such advanced systems, if commercial vehicles, such as those involved in the Mt. Pleasant Township crash, were equipped with advanced speed limiters and their carriers chose to set them to recognize and restrict speed to advisory speeds, drivers would be alerted to advisory speeds or, with a more active system, it would be difficult (or impossible, depending on the system) for drivers to exceed curve advisory speeds. Therefore, the NTSB concludes that, because advanced speed-limiting technology in vehicles can detect and respond to posted speed information and provide alerts, the technology can be used to help drivers avoid exceeding regulatory, advisory, and variable speed limits.

The NTSB has investigated multiple previous crashes involving motorcoaches that were speeding, including a 2011 motorcoach crash into a vertical signpost in New York City (NTSB 2012b) and a 2014 multivehicle work zone crash in Cranbury, New Jersey (NTSB 2015a). In its report on the 2011 crash in New York City, the NTSB issued Safety Recommendations H-12-20 and -21 to the National Highway Traffic Safety Administration (NHTSA):

H-12-20

Develop performance standards for advanced speed-limiting technology, such as variable speed limiters and intelligent speed adaptation devices, for heavy vehicles, including trucks, buses, and motorcoaches.

H-12-21

After establishing performance standards for advanced speed-limiting technology for heavy commercial vehicles, require that all newly manufactured heavy vehicles be equipped with such devices.

The NTSB reiterated both recommendations in the 2015 report on the Cranbury crash.

In NHTSA's response to Safety Recommendations H-12-20 and -21, the agency outlined its past and present activities concerning speed limiters. NHTSA stated that, in 2006, it received a petition from the American Trucking Associations and Road Safe America to initiate rulemaking to amend the FMVSSs to require vehicle manufacturers to limit the speed of heavy trucks. On January 26, 2007, NHTSA and the FMCSA jointly responded to the petitions with a request for comments notice in the *Federal Register*. On January 3, 2011, NHTSA published a notice granting the petitions for rulemaking and announced that the agency would initiate the rulemaking process with a notice of proposed rulemaking (NPRM). On September 7, 2016, NHTSA proposed to establish a new FMVSS requiring that each new multipurpose passenger vehicle, truck, bus, and school bus with a GVWR greater than 26,000 pounds be equipped with a traditional speed-limiting device meeting specified requirements.

The proposed rulemaking did not call for requiring advanced speed-limiting technologies such as those the NTSB recommended in Safety Recommendations H-12-20 and -21. NHTSA asserted that requiring advanced speed-limiting technology would not be feasible or cost-effective at that time. In its November 2, 2016, comments concerning the NPRM, the NTSB urged NHTSA to research the technology further and to conduct outreach to trucking and bus fleets currently using advanced speed-limiting technology.[109] Although the NTSB would have preferred NHTSA to

[109] For the full text, see NTSB comment on speed-limiting NPRM (comment ID NHTSA-2016-0087-1452; note that the comment from then-Chairman Christopher Hart of the NTSB is mislabeled as a NHTSA comment); accessed September 21, 2021. Since 2019, the European Union's safety regulations have focused on vehicle safety standards that integrate the use of intelligent speed assistance to prevent drivers from unintentionally exceeding the speed limit. By July 2022, according to General Safety Regulation 661/2009/ED (adopted November 27, 2019), new models of light vehicles in the European Union will be required to be equipped with those technologies to improve road safety. The regulation was recently amended (supplemented) to extend the requirement to all new light vehicles by 2024. Source: EUR-Lex - 32019R2144 - EN - EUR-Lex (europa.eu).

develop rulemaking requiring that all newly manufactured heavy vehicles be equipped with advanced speed-limiting technology, we supported the proposed rulemaking as an interim measure. However, in a November 13, 2017, letter, the NTSB noted that the NPRM did not meet the intent of the Safety Recommendations H-12-20 and -21, which were classified "Open—Unacceptable Response." Pending a final rule that requires the installation of advanced speed-limiting systems on newly manufactured heavy vehicles, Safety Recommendations H-12-20 and -21 remain classified "Open—Unacceptable Response." A final rule on advanced speed limiters has not been issued since the NPRM was published 5 years ago. The Mt. Pleasant Township crash shows the continuing need for the final rule that NHTSA has not issued. Therefore, the NTSB reiterates Safety Recommendations H-12-20 and -21 to NHTSA.

2.4 Collision Avoidance Systems

2.4.1 General

A collision avoidance (or mitigation) system is an advanced driver assistance system designed to prevent a crash or reduce its severity. Collision avoidance systems, through radar, cameras, and other sensors, monitor the environment for potential conflicts. Forward collision warning and AEB systems are designed to detect slow-moving or stopped vehicles in their lane of travel and prevent or mitigate rear-end collisions. When the system detects a potential conflict, it typically sends a warning to the driver, and if the driver does not respond or brake with sufficient force, the system automatically engages emergency braking.

The NTSB has a long history of investigating crashes involving rear-end collisions that could have been prevented or mitigated by forward collision warning and AEB systems. In 1995, the NTSB issued a safety recommendation to the DOT to conduct testing of collision warning technology in collaboration with the motor carrier industry (Safety Recommendation H-95-44).[110] Between 1995 and 2015, the NTSB issued more than two dozen recommendations related to collision avoidance systems. More recently, in 2015, the NTSB published a special investigation report (NTSB 2015b) in which we issued the following recommendation to NHTSA, currently classified "Open—Acceptable Response":

[110] Because of a lack of progress on the issue, Safety Recommendation H-95-44 was classified "Closed—Unacceptable Action" in August 1999. For more information about NTSB safety recommendations, see the Safety Recommendation Database at www.ntsb.gov.

H-15-5

> Complete, as soon as possible, the development and application of performance standards and protocols for the assessment of forward collision avoidance systems in commercial vehicles.

At that time, the NTSB also issued recommendations to passenger, bus, and truck manufacturers to install forward collision warning and AEB as standard equipment on their vehicles (Safety Recommendations H-15-8 and -9, currently classified "Open—Acceptable Response"). In parallel, the NTSB issued a recommendation to NHTSA to develop and apply testing protocols to assess the performance of forward collision avoidance systems in passenger vehicles at various velocities, including high speed and high velocity-differential (Safety Recommendation H-15-4 is currently classified "Open—Unacceptable Response").

Significant progress has been made in equipping passenger vehicles with forward collision avoidance systems—67 percent of 2020 vehicle models had forward collision avoidance as a standard feature.[111] However, the deployment of these systems as standard equipment in commercial vehicles is not prevalent.

In 2019, NHTSA published draft research test procedures for forward collision avoidance systems in commercial vehicles (Elasser, Salaani, and Boday 2019) and issued a request for comments on the procedures.[112] NHTSA intends to use these draft test procedures to further its research goals to better understand the systems' operation, performance, and potential limitations. The procedures included three scenarios for evaluating forward collision warning systems: (1) encountering a stopped vehicle in the same lane of travel, (2) encountering a slower-moving lead vehicle, and (3) following a vehicle that decelerates after a time.[113] The scenarios were to be conducted at different speeds, with a maximum speed differential between the test vehicle and the target vehicle of 25 mph. The stopped-lead-vehicle scenario was to be conducted at a single test vehicle speed of 25 mph. The test procedures did not include vehicle cut-out, in which a lead vehicle changes lanes to reveal a stopped vehicle ahead, or a cut-in scenario in which a vehicle suddenly switches lanes in front of the test vehicle. Both scenarios are extremely challenging for forward collision warning systems because of the minimal time for detecting a conflict and alerting the driver or engaging AEB.

[111] See the *Consumer Reports* "Guide to Cars with Advanced Safety Systems" (accessed November 15, 2021). The installation of forward collision avoidance systems in passenger vehicles is voluntary and subject to change.

[112] The request for comments also sought input regarding test procedures for advanced driver assistance systems for passenger vehicles.

[113] The same types of test scenarios are used for forward collision warning and AEB systems in passenger vehicles, as evaluated by NHTSA.

In the slower-moving-lead-vehicle scenario, the specified initial distance between the test and the target vehicles was to be greater than 100 meters (328 feet), which would allow an adequate time to reach the conditions of the test scenario but would also provide extended time during which the warning system could detect the lead vehicle. In this test scenario, the conflict-detection component begins when the time-to-contact between the vehicles drops to 5 seconds.[114] NHTSA specified two speed parameters for the test scenario, the higher of which includes the test vehicle and the slow-moving lead vehicle traveling at 47 mph and 22 mph, respectively.[115]

The research protocols specify that the target vehicle should be "representative of an actual vehicle approached from the rear," and that the tests should be conducted on a test track on a straight path and not during inclement weather.[116] The NTSB expressed concern about NHTSA's test protocols being set with ideal road conditions and below the typical speeds at which commercial vehicles travel, stating: "We strongly believe that it is important to strive for the performance we want the systems to be able to reach, not merely to test to the current capabilities of the systems."[117] NHTSA has yet to complete the development of performance standards for collision avoidance systems for commercial vehicles, as recommended in H-15-5. However, in spring 2021, for the first time, NHTSA included "Heavy Vehicle Automatic Emergency Braking" in the list of its regulatory and deregulatory actions (Unified Agenda, spring 2021, regulatory identification number 2127-AM36).

Despite a lack of federal standards for forward collision avoidance systems in commercial vehicles, some manufacturers have voluntarily installed the technology. Motor carriers such as UPS also require the systems for their fleets. For model year 2018 and above, Daimler voluntarily installed AEB as a standard feature in all its Cascadia trucks. The three Freightliner vehicles involved in the Mt. Pleasant Township crash were equipped with the Detroit Assurance safety system. The system functions as a standard forward collision warning system with AEB. On detecting a hazard, the system provides a warning, and if the driver does not respond or brake with sufficient force, it engages AEB to mitigate and potentially avoid a collision. The Detroit Assurance systems on the crash vehicles had slightly different capabilities, based on the version (2.0 or 4.0). The logged data showed that none of the forward collision

[114] Time-to-contact is based on the speed and the direction of the involved vehicles.

[115] The test parameters specify vehicle speed in kilometers per hour. The slower-moving-vehicle scenario specifies speeds of 40/15 and 75/35 kilometers per hour, respectively, for the test and lead vehicles.

[116] The NTSB understands that the phrase "actual vehicle approached from the rear" refers to the orientation of the test vehicle relative to the approaching vehicle. The test procedures assume that the stopped vehicle is upright, and that therefore its profile would be registered by the AEB system as a car, truck, or bus.

[117] See the NTSB's response to NHTSA's request for comments, "Advanced Driver Assistance Systems Draft Research Test Procedures," published at 84 *Federal Register* 64405 (November 21, 2019). https://www.regulations.gov/comment/NHTSA-2019-0102-0020

warning systems on the three vehicles provided an alert in the crash. The following sections explore the capabilities of forward collision warning systems and the circumstances of the impacts for each of the three vehicles.

2.4.2 Trucks Involved in Crash

FedEx Truck. The FedEx truck, traveling about 51 mph on the curve, encountered the underside of an overturned, stationary motorcoach that was positioned across all travel lanes and shoulders, leaving the truck with no room to maneuver around it. The motorcoach looked like a "black wall" to the FedEx driver.

The FedEx truck was equipped with the Detroit Assurance 4.0 safety system. The Detroit Assurance data showed that the system did not respond to the forward hazard. According to Daimler, Detroit Assurance 4.0 can detect stationary objects, although its stated capability does not specify the types or the orientation of the stationary objects. Furthermore, the system's design specifications do not state the speeds at which those capabilities are provided. Published information for the earlier version of Detroit Assurance—2.0—specifically states that the system responds only when it recognizes a detected object as a car, truck, or motorcycle. In previous investigations, the NTSB has examined the challenges in recognizing and classifying detected objects for developmental test vehicles with far more sophisticated sensors than those in the crash-involved trucks.[118]

The circumstances of the crash between the FedEx truck and the overturned motorcoach were outside the system's stated operational capabilities and exceeded NHTSA's research test protocols, in terms of (1) the vehicle's speed and the speed differential to the hazard (NHTSA's protocols include a test vehicle speed of only 25 mph), (2) the encountered hazard (the protocols include the rear of a vehicle as the only tested hazard), (3) the environmental conditions (the protocols are not designed for rain or snow), and (4) the geometry of the roadway (the protocols are designed for a straight roadway). As noted earlier, the safety system operates only in the absence of driver input, and the FedEx driver was applying the brakes.

UPS-1. Although Detroit Assistance 2.0 on this vehicle was not functional at the time of the crash, the NTSB examined whether the technology would have responded had it been functional (the maintenance of the system is discussed in section 2.3.4). UPS-1 was traveling in the left lane about 71 mph when the FedEx truck, traveling about 48 mph, began braking and changed lanes in front of it—about 541 feet ahead—before striking the overturned motorcoach.

[118] See the NTSB's report on its investigation of a 2018 crash involving a developmental automated driving system in Tempe, Arizona (NTSB 2019).

The crash scenario involving UPS-1 and the FedEx truck most closely resembles NHTSA's slower-moving-lead-vehicle scenario for testing forward collision avoidance systems, although it quickly transitioned to the stationary-lead-vehicle scenario. The crash scenario was also beyond NHTSA's research test parameters in terms of (1) vehicle speed (NHTSA's protocols include a test vehicle speed of up to 47 mph), and (2) the environmental conditions (the protocols are not designed for rain or snow). The speed differential of 23 mph between the vehicles at the time of the lane change was within that aspect of NHTSA's test parameters. However, the speed differential immediately began increasing because of the FedEx truck's high deceleration rate.

According to Daimler, Detroit Assurance 2.0 can detect moving and stationary objects, although the system's design specifications do not state the speeds at which those capabilities are provided. While we cannot determine whether the collision mitigation system on UPS-1 had operational capabilities to provide an alert, some of the characteristics of the impact were largely within NHTSA's proposed test protocols.

For 6 months before the crash, UPS-1 had been operating without an active brake assist system due to a misaligned radar sensor (which would have been presented to the driver as a fault warning light on the dashboard). The radar is required for the AEB to function. Although the misaligned sensor should have been detected during routine maintenance, it was not noted until July 26, 2019. At that time, the truck was pulled for service, and it was noted that it needed that repair in the future.[119] Consequently, the AEB system on UPS-1 was unavailable at the time of the crash.

Currently, there is no requirement for commercial vehicles to be equipped with collision avoidance systems. However, even when voluntarily installed, safety equipment must be maintained if it is to have any value in the event of an emergency. The NTSB concludes that maintaining the full functionality of installed collision avoidance systems is critical to vehicle safety, should a situation occur where collision avoidance is necessary. The issue of the failure to maintain the system in this case is discussed further in section 2.3.4.

UPS-2. UPS-2 was traveling in the right lane about 67 mph when it encountered the overturned motorcoach positioned across both westbound travel lanes and shoulders and the other two trucks with their brake lights illuminated. UPS-2 was equipped with the Detroit Assurance 2.0 safety system. The Detroit Assurance data show that the system did not respond to the forward hazard. The UPS-2 driver's

[119] A misaligned radar does not fall out of compliance with the *FMCSR*s and is not considered an out-of-service violation. Therefore, the condition does not require the vehicle to be placed out of service until after the issue is repaired or otherwise resolved.

early detection of the approaching hazard and steering off the roadway to the right most likely precluded the possibility of system activation.

The UPS-2 driver's response was essential, as the parameters of the developing potential crash between the UPS-2 and the overturned motorcoach were beyond NHTSA's proposed test protocols in terms of (1) vehicle speed and speed differential (NHTSA's protocols include a test vehicle speed of only 25 mph), (2) the encountered hazard (the protocols include the rear of a vehicle as the only tested hazard), and (3) the environmental conditions (the protocols are not designed for rain or snow).

According to Daimler, Detroit Assurance 2.0 was designed to respond only to objects it recognizes as a car, truck, or motorcycle. An overturned motorcoach lying across the travel lanes would not meet those object classifications. The circumstances and the parameters of the developing potential crash between UPS-2 and the overturned motorcoach were outside the system's stated operational capabilities and beyond NHTSA's research test protocols. Considering the conditions of this crash, the manufacturer's stated capabilities, and NHTSA's research test procedures, the NTSB concludes that the circumstances of the impacts for each of the three trucks were likely outside the capabilities of the collision avoidance system available on the vehicles and the parameters of NHTSA's research test procedures.

As discussed above, none of the forward collision warning systems on the three vehicles responded in the crash. Existing NHTSA test procedures for light vehicles and draft test procedures for heavy vehicles do not address the common scenarios involved in the crash, including weather conditions, curved roadway, and vehicle speed differential. The NTSB has expressed concern about the lack of federal standards and about the test velocities included in NHTSA's current test procedures because these are below the typical speeds at which commercial vehicles travel. The Insurance Institute for Highway Safety (IIHS) recently examined the effectiveness of forward collision avoidance in commercial vehicles to prevent rear-end crashes in real-world conditions (Teoh 2021). By examining real-world data, the IIHS determined that commercial vehicles equipped with forward collision warning were involved in 22 percent fewer rear-end crashes per miles traveled. Commercial vehicles equipped with forward collision warning and AEB were involved in 41 percent fewer rear-end crashes than vehicles without those systems.

Since the NTSB issued Safety Recommendation H-15-5, NHTSA has published draft test procedures for forward collision avoidance systems in commercial vehicles and added "Heavy Vehicle Automatic Emergency Braking" to its regulatory priorities, projecting the issuance of an NPRM by April 2022. The rulemaking will seek comments on proposed test procedures for measuring performance of forward collision avoidance and mitigation technology on heavy vehicles. Further, section 23010 ("Automatic Emergency Braking") of the Infrastructure Investment and Jobs Act (Public Law 117-58, signed on November 15, 2021) directs the DOT to prescribe a safety standard that requires commercial vehicles subject to FMVSS 136 ("Electronic Stability Control Systems for Heavy Vehicles") to be equipped with an AEB system.[120] The NTSB believes that, because commercial vehicles are more likely to travel on high-speed roads, it is reasonable that collision avoidance test protocols for those vehicles would include higher speeds. Other test parameters such as nonstraight paths and less-than-ideal weather conditions should be considered. Because forward collision avoidance and mitigation systems have the potential to prevent or mitigate the outcome of rear-end crashes such as the one that occurred near Mt. Pleasant Township, the NTSB reiterates Safety Recommendation H-15-5 to NHTSA.

2.4.3 Connected Vehicle Technologies

For the commercial trucks involved, the sensors residing on the vehicles might not have been capable of detecting the hazard posed by the overturned motorcoach and the dynamic conditions of the multivehicle, high-speed crash. However, another technology—connected vehicle technology—could potentially have addressed the complex precrash scenarios. Connected vehicle technology is also described as vehicle-to-everything (V2X), an umbrella term covering the various elements with which vehicles can communicate.[121]

V2X technology enables commercial and passenger vehicles to communicate with each other, with the infrastructure, and with other road vehicles, such as motorcycles. V2X-equipped vehicles securely send and receive vehicle performance information. The information communicated includes speed, position, braking, stability control system activation, and direction of travel, among other data. The technology acts as another sensor, or source of information, that is incorporated into the vehicle's own collision avoidance system, which would warn a driver or engage AEB in response to an upcoming hazard.[122]

V2X excels in several areas that are challenging for sensors installed on vehicles (vehicle-resident sensors). Specifically, V2X systems are not affected by curves, visibility, or crash scenarios that are challenging for vehicle-resident sensors to detect. Had the vehicles involved in the Mt. Pleasant Township crash been equipped with V2X technology, it would have allowed the overturned motorcoach to communicate to the approaching vehicles—FedEx truck, UPS-1, car, and UPS-2—that it was overturned and stopped ahead in their path. The vehicles that received the information could either have warned the drivers of the upcoming hazard—through a

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[120] FMVSS 136 is codified at 49 *CFR* 571.136 ("Electronic Stability Control").

[121] V2X is most frequently broken into (1) vehicle-to-vehicle (communication between vehicles) and (2) vehicle-to-infrastructure (communication between a vehicle and a *connected* infrastructure). V2X can also include vehicle-to-pedestrian (communication between a vehicle and *connected* pedestrians).

[122] For more information, see NHTSA's preliminary statement of policy on vehicle automation (May 2013), accessed September 21, 2021.

forward collision warning—or engaged AEB. Not all vehicles would have to be equipped with V2X technology to effect major safety improvements. In this case, the severity of the collision could have been significantly mitigated even if only the FedEx truck had provided connected vehicle information (such as hard-brake application) to the two following UPS trucks.

V2X communications can provide information about a threat much earlier than radar or camera sensors can detect the threat, giving drivers more time and a better opportunity to avoid a crash. V2X communications also provide a complementary source of information to vehicle-resident systems, improve the reliability and accuracy of data, extend the range of hazard detection, and detect crash risks that are outside a vehicle-resident sensor's field of view. The NTSB concludes that connected vehicle technology, if installed on the vehicles involved in the crash, could have provided information about the overturned motorcoach in the roadway to the FedEx truck, UPS-1, UPS-2, and the car, so that the drivers could be alerted to the hazard they were approaching, and the automated vehicle systems or the drivers might have prevented or mitigated the crashes involving those vehicles.

In 2013, in its report on its investigation of a February 2012 collision between a school bus and a truck at an intersection near Chesterfield, New Jersey (NTSB 2013), the NTSB made the following safety recommendations to NHTSA:

> <u>H-13-30</u>
>
> Develop minimum performance standards for connected vehicle technology for all highway vehicles.
>
> <u>H-13-31</u>
>
> Once minimum performance standards for connected vehicle technology are developed, require this technology to be installed on all newly manufactured highway vehicles.

In January 2017, NHTSA published an NPRM to establish a new FMVSS regarding vehicle-to-vehicle (V2V) communications. The new rulemaking would mandate connected vehicle technology, based on dedicated short-range communication (DSRC), in new light-duty vehicles and standardize the communication requirements of V2V messages.[123] The NTSB supported the mandate but expressed concern that it excluded heavy vehicles. In August 2018, the NTSB

[123] DSRC is a communication protocol used for V2X applications. NHTSA's 2017 proposed performance standard was based on the SAE International standards (J2735 and J2945) that define the message structure and the operational requirements for communication performance. A more recent, cellular-based communication protocol technology includes LTE-V2X and 5G-V2X, also known under an umbrella term of C-V2X; however, they are distinct communication protocol technologies.

classified Safety Recommendations H-13-30 and -31 "Open—Unacceptable Response" because NHTSA had made little progress toward implementing the recommendations and had taken no further regulatory action on V2V technologies since issuing the NPRM in January 2017. It is incumbent on NHTSA to develop minimum performance standards for connected vehicle technology for all highway vehicles. The NTSB responded that the benefits and necessity of connected vehicle technology is such that "the DOT should not put existing technologies, such as DSRC, on hold while waiting for the next emerging technology to arrive."[124] Because the Mt. Pleasant Township crash provides another example of a crash in which connected vehicle technology could have reduced the severity of the injuries, the NTSB reiterates Safety Recommendations H-13-30 and -31 to NHTSA.

Although V2X technology has advanced and its lifesaving benefits continue to be demonstrated, as reported following comprehensive analysis of a large-scale V2X deployment in Ann Arbor, Michigan (Nodine et al 2015), the future deployment of connected vehicles is in jeopardy due to recent regulatory actions by the Federal Communications Commission (FCC). In May 2021, the FCC finalized a ruling that decreased the spectrum allocated to V2X by 60 percent and introduced potential harmful interference by allowing unlicensed wi-fi devices the ability to operate in surrounding communication bands.[125] The interference concerns are longstanding and were acknowledged by the FCC as the primary risk factor to the agency's first proposal to reduce the safety spectrum in 2013.[126] However, the problem of interference has remained, and the concerns were again strongly voiced by the NTSB, US DOT agencies, and the broad automotive industry in their comments to the FCC's 2020 NPRM.[127] These concerns were based on research that examined the interference from the unlicensed wi-fi devices impacting the performance of connected vehicle devices. The research by NHTSA, the Crash Avoidance Metrics Partnership (CAMP) consortium, and Ford showed not only that interference from unlicensed wi-fi devices exists, but also that the extent of wi-fi intrusion would essentially render the safety-critical V2X applications that rely on low latency and high reliability, severely compromised and ineffective, regardless of the communication protocol technology used in the 30 MHz safety spectrum (NHTSA 2019; CAMP 2020;

[124] See NTSB letter to Rules Docket DOT-OST-2018-0210, March 11, 2019, in response to Notice of Request for Comment, "V2X Communications," published in 83 *Federal Register* 66338 (December 26, 2018).

[125] For the new ruling, see 86 *Federal Register* 23281 (May 3, 2021).

[126] (a) This FCC notice of proposed rulemaking was issued February 20, 2013.

(b) Following the overwhelming negative comments to this proposal, the FCC paused the progression of this rulemaking, citing possible interference from the unlicensed devices as a risk factor. In the NTSB response, the Board stated concern that interference from unlicensed devices could affect the integrity of transportation safety communication.

[127] For the NPRM, see 85 *Federal Register* 6841 (February 6, 2020).

Ford 2020).[128] In the NTSB's comments to the FCC, the Board stated that sharing of the spectrum "would be detrimental to safety and dramatically set back advancements in transportation safety." However, despite the very strong concerns expressed by transportation safety stakeholders, the FCC finalized the ruling to reduce and temporarily share the safety spectrum, introducing harmful interference.[129] The NTSB concludes that recent regulatory action by the FCC that decreases the size of the intelligent transportation system communication spectrum and allows harmful interference from unlicensed devices, such as those that use wi-fi, threatens the future deployment of connected vehicle technology. Therefore, the NTSB recommends that the FCC implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference from unlicensed devices, such as those that use wi-fi.

In 2021, in an effort to better understand the impact of the FCC's recent actions to limit the spectrum available for transportation safety, the NTSB interviewed stakeholders from government, industry, and academia about the safety benefits and maturity level of V2X technology and the reasons for the scarce deployment of the technology.[130] During the in-depth discussions with experts, three critical hurdles were identified as issues preventing the broad deployment of V2X: sufficiency of spectrum, interference from unlicensed wi-fi devices, and regulatory uncertainty. In examining the sufficiency of spectrum, ITS America released a report specifying the large number of safety applications that will not be possible given the reduced size of the spectrum.[131] Among the applications that will not be possible include those that are critical for the development and deployment of automated vehicles and enhanced mobility.

The lack of regulatory certainty regarding the future direction of the communications protocol and spectrum availability has been cited by experts as the primary reason V2X deployment is in jeopardy. Before the FCC's actions, some infrastructure owner-operators and automakers were investing in research and deployment of V2X technology. Since the FCC's rulemaking, action has been

[128] The NHTSA research examined the impact of interference from unlicensed wi-fi devices on the communication performance of DSRC-connected vehicle devices, while CAMP and Ford examined the impact of interference on the performance of LTE-V2X devices.

[129] In their comments, the Alliance for Automotive Innovation (an association representing nearly all automakers in the United States) stated that "the FCC's proposed band plan would be tantamount to eliminating V2X." Similar concerns were expressed by other automotive industry stakeholders.

[130] Refer to the four-part Most Wanted List interview video series moderated by NTSB Board Member Michael Graham. Episode 1 of the series provides an overview of V2X technology, effectiveness research, and a discussion of wi-fi interference. Episode 2 discusses the impact of FCC actions and global advancements in V2X technology. Episode 3 examines infrastructure deployment and state DOT perspective. Episode 4 is focused on the obstacles to deployment with perspectives from two major auto manufacturers.

[131] ITS-America-30-MHz-Application-Map-1-27.21.pdf (itsa.org).

hindered. Other critical issues impacting deployment include the DOT's lack of concrete steps since 2017 when the proposed V2V rulemaking stalled, industry division regarding the type of communication protocol to use, and automakers reluctance to invest in such an uncertain environment. With such confluence of critical factors, it is imperative that DOT take a prominent leadership role to ensure an optimal environment for deployment. The NTSB concludes that leadership from the US DOT is needed to establish regulatory certainty and resolve critical issues related to V2X communication protocols; interference from unlicensed devices, such as those that use wi-fi; and sufficiency of communication spectrum needed for advanced connected vehicle applications.

Therefore, the NTSB recommends that the DOT implement a plan for nationwide connected vehicle technology deployment that (1) resolves issues related to interference from unlicensed devices, such as those that use wi-fi; (2) ensures sufficient spectrum necessary for advanced connected vehicle applications; and (3) defines communication protocols to be used in future connected vehicle deployment.

2.4.4 Reporting Nonfunctional Safety Systems

A postcrash download of the electronic data for UPS-1 indicated an issue with its Detroit Assurance 2.0 system. The radar sensor for the active brake assist system had been misaligned since June 2019. The deficiency would have been indicated by a fault warning light on the vehicle dashboard; however, no driver indicated on a DVIR for the vehicle that the warning light had activated. Likewise, UPS did not report the issue to Penske (from which UPS leased the truck) during the truck's regularly scheduled maintenance, which Penske performed. However, Penske's maintenance records for July 2019, September 2019, November 2019, and December 2019 noted this fault. The service notes from the December maintenance indicated that the dashboard warning light was on, showing that active brake assist was unavailable but that the "driver didn't write up for issue."

At the time of the crash, the UPS procedure for addressing vehicle faults was that UPS drivers would notify the on-road supervisor if they discovered vehicle defects or issues. The driver was required to fill out a DVIR and contact Penske directly concerning the issue. Penske either sent a service truck to the UPS hub or had the driver take the truck to the Penske facility if it was safe to do so. If the vehicle repair would take an extended period, the truck would be taken out of service for repairs and a substitute truck would be provided. Penske did not require service technicians to send paperwork to the UPS hub describing the work performed or any items that needed repair. Penske would document the issue or repairs in an internal Penske database, which was accessible by UPS; however, Penske did not notify UPS of any defects or issues found. To check on its vehicles' faults, UPS would have to proactively check the Penske database.

Although collision avoidance and AEB systems are designed to prevent crashes, the FMCSA does not require them to be reported as safety systems necessary for safe operation on DVIRs because NHTSA has not yet designated collision avoidance systems as required equipment. Despite this lack of designation, any motor carrier is free to add elements not required by NHTSA to its DVIR forms. Moreover, all DVIR forms have a blank space where drivers may write in any vehicle issues, even if the relevant vehicle element is not identified on the preprinted form.

The NTSB is concerned that, if safety technologies such as collision avoidance systems are not specifically identified on DVIR forms as safety systems, drivers may fail to report faults concerning them on the form, as occurred in this case. Without specific guidance on the form and associated training, drivers might not document on the DVIR a defect in forward collision avoidance or AEB systems. Without the notification for intervention (and repair) provided by a DVIR, a malfunctioning safety system could remain inoperative or faulty until a crash occurs.

UPS recognizes the safety benefit provided by collision avoidance systems in preventing or mitigating rear-end collisions, and it contractually requires that AEB systems be installed on all the vehicles that it leases. These systems are effective only when they are operational and free from fault, which requires appropriate maintenance. DVIRs are crucial to flagging vehicle faults requiring repair, and they must reflect the full range of vehicle issues—including those concerning collision avoidance systems, even if the systems are not required. The NTSB concludes that if drivers report defects or faults in collision avoidance systems on DVIR forms, repairs can be made more readily, thus improving the operational safety of the vehicle. Therefore, the NTSB recommends that the American Trucking Associations, the Owner-Operator Independent Drivers Association, the Commercial Vehicle Safety Alliance, the American Bus Association, the United Motorcoach Association, the Transport Workers Union of America, the Amalgamated Transit Union, and the International Brotherhood of Teamsters inform their members about the importance of drivers reporting faults concerning advanced safety features, such as AEB, in the optional section of the DVIR form (if they are not already identified on the form).

Both FedEx and UPS represent large portions of the commercial vehicle fleet in the United States. Since the crash, UPS has proactively incorporated into its driver training the need for drivers to check for issues concerning advanced safety features, such as AEB and lane departure warning. FedEx has not made such changes to its driver training. Neither FedEx nor UPS has specifically required that its drivers report such issues on the DVIR forms (although FedEx has told the NTSB that it is evaluating its DVIR form to determine if it needs to be updated to include advanced safety systems). Therefore, the NTSB recommends that FedEx and UPS require their drivers to report faults concerning advanced safety features, such as AEB, in the optional section of the DVIR form (if they are not already identified on the form).

The NTSB also recognizes the need to expand to all motor carriers the addition of collision avoidance systems to the DVIR form, not just for the carriers involved in this crash. Therefore, the NTSB recommends that the FMCSA add collision avoidance systems, including AEB, to the parts and accessories listed at 49 *CFR* section 396.11 (a)(1) that the DVIR form will include.

2.5 Onboard Video Event Recorder Systems on Commercial Motor Vehicles

Although the motorcoach and the three trucks were equipped with ECMs that collected data useful to understand the collision sequence, the information was insufficient to determine why the motorcoach experienced an initial loss of control and why the driver may have entered excessive steering resulting in the crash with the embankment. Further, ruling out driver fatigue in the loss-of-control scenario was challenging, and to determine the likely engagement of the engine brake required a detailed simulation because of crash-related damage to the instrument panel, where the engine brake switch is located. In comparison, the FedEx truck was equipped with a Lytx DriveCam system that recorded forward- and inward-facing video, as well as speed, acceleration, and other parametric data, enabling understanding of the FedEx driver's performance as the truck approached the overturned motorcoach. The video recording system on board the FedEx truck also provided valuable information about the speed and lane position of the motorcoach as it passed the FedEx truck shortly before the motorcoach's loss of control. The system documented the position of the overturned motorcoach on the roadway and its visibility as the FedEx truck approached. Further, the inward-facing video, along with the parametric data recorded by the Drivecam system, documented that the FedEx driver reacted quickly to an unknown and difficult-to-observe hazard. Finally, the system recorded the FedEx truck's speed and enabled investigators to understand the severity of the initial crash and the subsequent crash by the UPS-1 truck.

NTSB investigations into underlying safety issues associated with crashes have previously been aided by data obtained from onboard video recording systems. In January 2008 near Mexican Hat, Utah, a motorcoach equipped with a DriveCam II event-based video system ran off the road and overturned (NTSB 2009). The recorded data enabled investigators to determine the speed of the motorcoach and to confirm that its headlights were illuminated at the time of the evening crash. The video also provided the basis for evaluating the driver and passengers, such as verifying that the driver was not using a cell phone, and examining the actions of both the driver and passengers leading up to the roadway departure. Although the DriveCam II system recorded only 20 seconds surrounding the crash event, the recorded data were critical to understanding the motorcoach driver's fatigue.

The investigation of a truck-tractor semitrailer rear-end collision into passenger vehicles on I-44 near Miami, Oklahoma, resulted in the NTSB issuing two safety recommendations (H-10-10 and -11) to the FMCSA concerning event-based video systems in commercial vehicles weighing more than 10,000 pounds (NTSB 2010).

> H-10-10:
>
> Require all heavy commercial vehicles to be equipped with video event recorders that capture data in connection with the driver and the outside environment and roadway in the event of a crash or sudden deceleration event. The device should create recordings that are easily accessible for review when conducting efficiency testing and systemwide performance-monitoring programs.
>
> H-10-11:
>
> Require motor carriers to review and use video event recorder information in conjunction with other performance data to verify that driver actions are in accordance with company and regulatory rules and procedures essential to safety.

The objective of these two recommendations was to proactively monitor and modify risky driver behavior and to improve investigative data collection, steps that may have been valuable for the motorcoach driver in the Mt. Pleasant Township crash. In June 2019, the NTSB classified Safety Recommendations H-10-10 and -11 "Closed—Unacceptable Action," because the FMCSA did not take the step to require all heavy commercial vehicles to be equipped with video event recorders. 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.

The NTSB continued to benefit from video recording systems in subsequent investigations. The onboard video system in the 2013 school bus crash in Port Saint Lucie, Florida, provided critical insight that the bus driver was not distracted and had both hands on the steering wheel during his left-turn maneuver. It was also clear that the driver perceived the risk of the oncoming truck, though too late, because he turned his head toward the oncoming truck. The onboard video and associated audio recording showed that the driver encouraged seat belt use at the beginning of the trip and that he did not appear to be distracted by students before the collision. Based on the inward-facing video footage, extensive information was documented related to passenger behavior, restraint usage patterns, and injury causation during the crash sequence. The benefits of the onboard video recording system in the Port Saint Lucie crash—as well as the problems with low-light recording in such a system in a 2011 Kearney, Nebraska, motorcoach crash—were explored in the NTSB's 2015 report *Commercial Vehicle Onboard Video Systems* (NTSB 2015c). As a result of these investigations, the NTSB concluded that onboard video systems can provide valuable information for evaluating the circumstances leading to a crash, as well as providing critical vehicle dynamics and occupant kinematics data for assessing crash survivability. Further as a result of the Port Saint Lucie and Kearney investigations, the NTSB issued Safety Recommendation H-15-2 to the American Bus Association, the United Motorcoach Association, the American Trucking Associations, the American Public Transportation Association, the National Association for Pupil Transportation, the National Association of State Directors of Pupil Transportation Services, and the National School Transportation Association:

> Encourage your 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-15-2 is classified "Open—Await Response" to the American Bus Association and the United Motorcoach Association.

Understanding what factors, in addition to speed, led to the motorcoach's initial loss of control in the Mt. Pleasant Township crash and why the driver may have entered excessive steering input is critical to implementing effective safety countermeasures. The voluntarily installed onboard video event recorder system on the FedEx truck provided critical information about the motorcoach, the FedEx driver's quick response, and the severity of the initial and subsequent crashes. In addition, with advanced technologies such as collision avoidance systems on commercial vehicles, onboard video event recorder systems can provide critical information on the performance and functionality of these systems. The NTSB concludes that the forward- and inward-facing video event recorder system on the FedEx truck provided valuable information on the speed and operation of the motorcoach as it passed the FedEx truck, the hazard presented by the overturned motorcoach blocking all travel lanes, the FedEx driver's response to the overturned motorcoach, and the severity of the initial collision and the subsequent collision by the UPS-1 truck. The NTSB also concludes that onboard video event recorder systems, providing at a minimum visibility forward of the vehicle and inward toward the driver's face and instrument panel and parametric data associated with the event, such as real clock time, GPS location, and acceleration data, 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. The presence of onboard video event data recorder systems on all commercial motor vehicles, in combination with a driver management or coaching program, could assist carriers to identify and address factors in motor carrier operations and driver behavior that increase crash risk. Therefore, the NTSB concludes that information from onboard video event recorder systems can proactively be used by motor carriers to aid in driver training and address driver behaviors that have crash risks associated with them. Therefore, the NTSB recommends that NHTSA 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. The NTSB further recommends that the FMCSA provide guidance to motor carriers to proactively use the onboard video event recorder information to aid in driver training and ensure driver compliance with regulatory rules essential for safe operation. Lastly, the NTSB reiterates Safety Recommendation H-15-2 to the American Bus Association and the United Motorcoach Association to voluntarily install onboard video systems.

3. Conclusions

3.1 Findings

1. None of the following were factors in the crash: (1) qualifications of the motorcoach driver, (2) use of alcohol or other drugs by the motorcoach driver, (3) cell phone use by the motorcoach driver, (4) mechanical condition of the motorcoach, (5) pavement condition, and (6) roadway salt treatment used to address the freezing conditions.

2. The emergency response to the crash, including transportation of the injured, was timely and effective.

3. Although the motorcoach driver had adequate opportunities for sleep in the days before the crash, when and how long he slept and the quality of any sleep he had could not be determined.

4. The evidence is insufficient to establish that fatigue was a factor in the crash.

5. The motorcoach's engine brake was likely engaged at the time of the crash when the driver released the service brake and the throttle.

6. For unknown reasons, the motorcoach driver likely made excessive steering inputs beyond those needed to negotiate the curve.

7. The motorcoach driver was traveling too fast for the wet roadway conditions, on a curve with the engine brake likely engaged, resulting in a loss of vehicle control that led to the roadway departure and impact with the right-side embankment.

8. The motorcoach driver's likely use of the engine brake on the curve where the crash occurred reduced the available traction on the roadway.

9. Because the FedEx truck was traveling at a reduced speed when the driver became aware of the overturned motorcoach, the driver had time to react by braking, thus mitigating the severity of the truck's impact with the motorcoach.

10. Although the driver of UPS-1 attempted to avoid the impact with the rear of the FedEx truck, UPS-1's initial speed was too fast for the wet roadway conditions and made the driver's braking attempts ineffective in substantially reducing his vehicle's speed before the impact, contributing to the severity of the injuries sustained by the motorcoach passengers and the UPS-1 drivers.

11. The UPS-2 driver most likely had cues to the slowing and crashed vehicles ahead, enabling him to reduce the truck's speed, steer to the right, and therefore inflict only minor damage to the car stopped alongside UPS-1.

12. Had variable speed limit signs that change the regulatory speed limit and are enforceable, such as by speed safety cameras, been used to inform the drivers involved in the crash to slow to a speed more appropriate for a wet road surface, they would have been more likely to travel at lower speeds, which could have prevented or mitigated the crash.

13. The 85th percentile speed used in the Federal Highway Administration's tools, USLIMITS2 and the National Cooperative Highway Research Program 966, to set appropriate speed limits on all roadways is outdated and should be de-emphasized.

14. Speed safety cameras are an effective countermeasure to reduce speeding-related crashes, fatalities, and injuries.

15. Because advanced speed-limiting technology in vehicles can detect and respond to posted speed information and provide alerts, the technology can be used to help drivers avoid exceeding regulatory, advisory, and variable speed limits.

16. Maintaining the full functionality of installed collision avoidance systems is critical to vehicle safety, should a situation occur where collision avoidance is necessary.

17. The circumstances of the impacts for each of the three trucks were likely outside the capabilities of the collision avoidance system available on the vehicles and the parameters of the National Highway Traffic Safety Administration's research test procedures.

18. Connected vehicle technology, if installed on the vehicles involved in the crash, could have provided information about the overturned motorcoach in the roadway to the FedEx truck, UPS-1, UPS-2, and the car, so that the drivers could be alerted to the hazard they were approaching, and the automated vehicle systems or the drivers might have prevented or mitigated the crashes involving those vehicles.

19. Recent regulatory action by the Federal Communications Commission that decreases the size of the intelligent transportation system communication spectrum and allows harmful interference from unlicensed devices, such as those that use wi-fi, threatens the future deployment of connected vehicle technology.

20. Leadership by the US Department of Transportation is needed to establish regulatory certainty and resolve critical issues related to vehicle-to-everything communication protocols; interference from unlicensed devices, such as those that use wi-fi; and sufficiency of communication spectrum needed for advanced connected vehicle applications.

21. If drivers report defects or faults in collision avoidance systems on driver vehicle inspection report forms, repairs can be made more readily, thus improving the operational safety of the vehicle.

22. The forward- and inward-facing video event recorder system on the FedEx truck provided valuable information on the speed and operation of the motorcoach as it passed the FedEx truck, the hazard presented by the overturned motorcoach blocking all travel lanes, the FedEx driver’s response to the overturned motorcoach, and the severity of the initial collision and the subsequent collision by the UPS-1 truck.

23. Onboard video event recorder systems, providing at a minimum visibility forward of the vehicle and inward toward the driver’s face and instrument panel and parametric data associated with the event, such as real clock time, GPS location, and acceleration data, 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.

24. Information from onboard video event recorder systems can proactively be used by motor carriers to aid in driver training and address driver behaviors that have crash risks associated with them.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the crash near Mt. Pleasant Township, Pennsylvania, was the motorcoach driver’s loss of control due to the motorcoach’s unsafe speed on the wet curve and the driver’s likely excessive steering inputs, which caused the motorcoach to run off the road, strike an embankment, and subsequently roll over across the roadway, which led to two commercial trucks colliding with the motorcoach. Contributing to the severity of the crash was the high initial and impact speed of the second truck.

4. Recommendations

4.1 New Recommendations

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

To the US Department of Transportation:

Implement a plan for nationwide connected vehicle technology deployment that (1) resolves issues related to interference from unlicensed devices, such as those that use wi-fi; (2) ensures sufficient spectrum necessary for advanced connected vehicle applications; and (3) defines communication protocols to be used in future connected vehicle deployment. (H-22-1)

To the Federal Highway Administration:

Evaluate the applicability and use of the 85th percentile speed input variable in both of your tools, USLIMITS2 and the National Cooperative Highway Research Program 966, for setting appropriate speed limits to reduce serious and fatal injuries. (H-22-2)

To the National Highway Traffic Safety Administration:

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 Federal Motor Carrier Safety Administration:

Provide guidance to motor carriers to proactively use the onboard video event recorder information to aid in driver training and ensure driver compliance with regulatory rules essential for safe operation. (H-22-4)

Add collision avoidance systems, including automatic emergency braking, to the parts and accessories listed at 49 *Code of Federal Regulations*, section 396.11 (a)(1) that the driver vehicle inspection report form will cover. (H-22-5)

To the Federal Communications Commission:

Implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference from unlicensed devices, such as those that use wi-fi. (H-22-6)

To the Commonwealth of Pennsylvania:

Seek authority to allow speed safety cameras to be used on the Pennsylvania Turnpike outside of active work zones. (H-22-7)

To the Pennsylvania Turnpike Commission:

Implement the use of variable speed limit signs or other similar technology to adjust statutory speeds based on real-time information regarding weather and road conditions. (H-22-8)

To the American Trucking Associations, the Owner-Operator Independent Drivers Association, the Commercial Vehicle Safety Alliance, the American Bus Association, the United Motorcoach Association, the Transport Workers Union of America, the Amalgamated Transit Union, and the International Brotherhood of Teamsters:

Inform your members about the importance of drivers reporting faults concerning advanced safety features, such as automatic emergency braking, in the optional section of the driver vehicle inspection report form (if they are not already identified on the form). (H-22-9)

To the American Bus Association and the United Motorcoach Association:

Inform your members about the circumstances of the Mt. Pleasant Township crash, the importance of drivers following the Federal Motor Carrier Safety Administration's guidance on engine retarders, "Motorcoach Brake Systems and Safety Technologies," and the need to incorporate the guidance into their members' training and manuals. (H-22-10)

To FedEx Ground Package System and United Parcel Service of America:

Require your drivers to report faults concerning advanced safety features, such as automatic emergency braking, in the optional section of the driver vehicle inspection report form (if they are not already identified on the form). (H-22-11)

4.2 Previously Issued Recommendations Reiterated in This Report

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

To the National Highway Traffic Safety Administration:

> Develop performance standards for advanced speed-limiting technology, such as variable speed limiters and intelligent speed adaptation devices, for heavy vehicles, including trucks, buses, and motorcoaches. (H-12-20)
>
> After establishing performance standards for advanced speed-limiting technology for heavy commercial vehicles, require that all newly manufactured heavy vehicles be equipped with such devices. (H-12-21)
>
> Develop minimum performance standards for connected vehicle technology for all highway vehicles. (H-13-30)
>
> Once minimum performance standards for connected vehicle technology are developed, require this technology to be installed on all newly manufactured highway vehicles. (H-13-31)
>
> Complete, as soon as possible, the development and application of performance standards and protocols for the assessment of forward collision avoidance systems in commercial vehicles. (H-15-5)

To the Commonwealth of Pennsylvania:

> Authorize state and local agencies to use automated speed enforcement. (H-17-32)

To the American Bus Association and the United Motorcoach Association:

> Encourage your 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. (H-15-2)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

MICHAEL GRAHAM
Member

BRUCE LANDSBERG
Vice Chairman

THOMAS CHAPMAN
Member

Report Date: February 8, 2022

Appendix A: Investigation

The NTSB received notification of the Mt. Pleasant Township crash on January 5, 2020, and launched investigators that day from the Office of Highway Safety to address highway and vehicle factors, motor carrier operations, human performance, and survival factors. The team included staff from the NTSB's Transportation Disaster Assistance Division. Jennifer Homendy, now NTSB chair, was the board member on scene. The NTSB's Office of Research and Engineering participated in the investigation.

United Parcel Service of America, FedEx Ground Package System, Daimler Trucks North America, the Pennsylvania State Police, the Pennsylvania Turnpike Commission, and the FMCSA's Pennsylvania division were parties to the investigation.

Appendix B: Consolidated Recommendation Information

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

For each recommendation—

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

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

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

To the US Department of Transportation:

H-22-1

Implement a plan for nationwide connected vehicle technology deployment that (1) resolves issues related to interference from unlicensed devices, such as those that use wi-fi; (2) ensures sufficient spectrum necessary for advanced connected vehicle applications; and (3) defines communication protocols to be used in future connected vehicle deployment.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.3 Connected Vehicle Technology. Information supporting (b)(1) and (b)(2) can be found on pages 81–85; (b)(3) is not applicable.

To the Federal Highway Administration:

H-22-2

Evaluate the applicability and use of the 85th percentile speed input variable in both of your tools, USLIMITS2 and the National Cooperative Highway Research Program 966, for setting appropriate speed limits to reduce serious and fatal injuries.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3 Vehicle Speed. Information supporting (b)(1) and (b)(2) can be found on pages 62–63; (b)(3) is not applicable.

To the National Highway Traffic Safety Administration:

H-22-3

> 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.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5 Onboard Video Event Recorder Systems on Commercial Motor Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 87–90; (b)(3) is not applicable.

To the Federal Motor Carrier Safety Administration:

H-22-4

> Provide guidance to motor carriers to proactively use the onboard video event recorder information to aid in driver training and ensure driver compliance with regulatory rules essential for safe operation.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5 Onboard Video Event Recorder Systems on Commercial Motor Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 87–90; (b)(3) is not applicable.

H-22-5

> Add collision avoidance systems, including automatic emergency braking, to the parts and accessories listed at 49 *Code of Federal Regulations*, section 396.11 (a)(1) that the driver vehicle inspection report form will cover.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.4 Reporting Nonfunctional Safety Systems. Information supporting (b)(1) and (b)(2) can be found on pages 85–87; (b)(3) is not applicable.

To the Federal Communications Commission:

H-22-6

> Implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference from unlicensed devices, such as those that use wi-fi.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.3 Connected Vehicle Technology. Information supporting (b)(1) and (b)(2) can be found on pages 81–85; (b)(3) is not applicable.

To the Commonwealth of Pennsylvania:

H-22-7

> Seek authority to allow speed safety cameras to be used on the Pennsylvania Turnpike outside of active work zones.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.5 Speed Countermeasures. Information supporting (b)(1) and (b)(2) can be found on pages 68–71; (b)(3) is not applicable.

To the Pennsylvania Turnpike Commission:

H-22-8

> Implement the use of variable speed limit signs or other similar technology to adjust statutory speeds based on real-time information regarding weather and road conditions.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.5 Speed Countermeasures. Information supporting (b)(1) and (b)(2) can be found on pages 68–71; (b)(3) is not applicable.

To the American Trucking Associations, the Owner-Operator Independent Drivers Association, the Commercial Vehicle Safety Alliance, the American Bus Association, the United Motorcoach Association, the Transport Workers Union of America, the Amalgamated Transit Union, and the International Brotherhood of Teamsters:

H-22-9

> Inform your members about the importance of drivers reporting faults concerning advanced safety features, such as automatic emergency

> braking, in the optional section of the driver vehicle inspection report form (if they are not already identified on the form).

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.4 Reporting Nonfunctional Safety Systems. Information supporting (b)(1) and (b)(2) can be found on pages 85–87; (b)(3) is not applicable.

To the American Bus Association and the United Motorcoach Association:

H-22-10

> Inform your members about the circumstances of the Mt. Pleasant Township crash, the importance of drivers following the Federal Motor Carrier Safety Administration's guidance on engine retarders, "Motorcoach Brake Systems and Safety Technologies," and the need to incorporate the guidance into their members' training and manuals.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3 Vehicle Speed. Information supporting (b)(1) and (b)(2) can be found on pages 63–67; (b)(3) is not applicable.

To FedEx Ground Package System and United Parcel Service of America:

H-22-11

> Require your drivers to report faults concerning advanced safety features, such as automatic emergency braking, in the optional section of the driver vehicle inspection report form (if they are not already identified on the form).

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.4 Reporting Nonfunctional Safety Systems. Information supporting (b)(1) and (b)(2) can be found on pages 85–87; (b)(3) is not applicable.

References

AASHTO (American Association of State Highway and Transportation Officials). 2018. *A Policy on Geometric Design of Highways and Streets.* 7th ed. Washington, DC: AASHTO.

CAMP. 2020. *C-V2X Performance Assessment Project Task 8: Assessment of Wi-Fi Interference to C-V2X Communication Based on Proposed FCC 5.9 GHz NPRM.* CAMP–C-V2X Consortium.

Elasser, D., M. K. Salaani, and C. Boday. 2019. *Test Track Procedures for Heavy-Vehicle Forward Collision Warning and Automatic Emergency Braking Systems*. DOT HS 812 675. Washington, DC: NHTSA.

Federal Highway Administration (FHWA). 2012. *Guidelines for the Use of Variable Speed Limit Systems in Wet Weather*. Report FHWA-SA-022. Washington, DC: FHWA.

_____. 2017. *Synthesis of Variable Speed Limit Signs*. Report FHWA-HOP-17-003. Washington, DC: FHWA.

_____. 2021. *Speed Safety Cameras - Safety | Federal Highway Administration*. Report HWA-SA-21-070. Washington, DC: FHWA.

Federal Motor Carrier Safety Administration (FMCSA). 2005. *Report to Congress on the Large Truck Crash Causation Study.* Report MC-R/MC-RIA. Washington, DC: FMCSA.

_____. 2007. *Motorcoach Brake Systems and Safety Technologies*. Publication FMCSA-ESO-07-01. Washington, DC: FMCSA.

Ford letter "Comments of the Ford Motor Company," sent March 9, 2020, to the FCC ET Docket No. 19-138. Goodwin, L., and P. Pisano. 2003. *Best Practices for Road Weather Management*. Washington, DC: FHWA.

Lisper, H.-O., H. Laurell, and J. van Loon. 1986. "Relation Between Time to Falling Asleep Behind the Wheel on a Closed Track and Changes in Subsidiary Reaction Time During Prolonged Driving on a Motorway." *Ergonomics* 19 (3): 445–453.

Montella et al. 2015. "Effects on Speed and Safety of Point-to-Point Speed Enforcement Systems: Evaluation on the Urban Motorway A56 Tangenziale di Napoli." *Accident Analysis and Prevention*, Vol. 75.

National Highway Traffic Safety Administration (NHTSA). 2021. *Traffic Safety Facts: Speeding*. Report DOT-HS-813-194. Washington, DC: NHTSA.

National Transportation Safety Board (NTSB). 2002. *Motorcoach Run-Off-Road Near Cañon City, Colorado, December 21, 1999*. Highway Accident Brief NTSB/HAB-02/19. Washington, DC: NTSB.

_____. 2005. *Motorcoach Median Crossover and Collision With Sport Utility Vehicle, Hewitt, Texas, February 14, 2003*. Highway Accident Report NTSB/HAR-05/02. Washington, DC: NTSB.

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

____. 2012a. *Motorcoach Roadway Departure and Overturn on Interstate 95 Near Doswell, Virginia, May 31, 2011*. Highway Accident Report NTSB/HAR-12/02. Washington, DC: NTSB.

____. 2012b. *Motorcoach Run-Off-the-Road and Collision With Vertical Highway Signpost, Interstate 95 Southbound, New York City, New York, March 12, 2011.* Highway Accident Report NTSB/HAR-12/01. Washington, DC: NTSB.

_____. 2013. *School Bus and Truck Collision at Intersection Near Chesterfield, New Jersey, February 16, 2012*. Highway Accident Report NTSB/HAR-13/01. Washington, DC: NTSB.

_____. 2015a. *Multivehicle Work Zone Crash on Interstate 95, Cranbury, New Jersey, June 7, 2014.* Highway Accident Report NTSB/HAR-15-02. Washington, DC: NTSB.

_____. 2015b. *The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes.* Special Investigation Report NTSB/SIR-15/01. Washington, DC: NTSB.

_____. 2015c. *Commercial Vehicle Onboard Video Systems*. Safety Report NTSB/SR-15/01. Washington, DC: NTSB.

_____. 2017. *Reducing Speeding-Related Crashes Involving Passenger Vehicles.* Safety Study NTSB/SS-17/01. Washington, DC: NTSB.

_____. 2019. *Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian, Tempe, Arizona, March 18, 2018*. Highway Accident Report NTSB/HAR-19/03. Washington, DC: NTSB.

Pilcher, J. J., B. J. Lambert, and A. I. Huffcutt. 2000. "Differential Effects of Permanent and Rotating Shifts on Self-Report Sleep Length: A Meta-Analytic Review." *Sleep* 23 (2): 155163.

Schwartz, A.R., S. P Patel, A. M. Laffan. V. Polotsky, H. Schneider, and P. L. Smith. 2008. "Obesity and Obstructive Sleep Apnea: Pathogenic Mechanisms and Therapeutic Approaches." *Proceedings of the American Thoracic Society* 5(2): 185–192.

Teoh, Eric, R. 2021. "Effectiveness of Front Crash Prevention Systems in Reducing Large Truck Real-World Crash Rates." *Traffic Injury Prevention*. 22(4): 284–289. Arlington, VA: Insurance Institute for Highway Safety.

Van Dongen, H.P.A., and D. Dinges. 2005. "Circadian Rhythms in Sleepiness, Alertness, and Performance," in M. H. Kryger, T. Roth, and W. C. Dement (eds.) *Principles and Practice of Sleep Medicine*, 4th edition. Philadelphia, Pennsylvania: Saunders Company.

VanSickle, S. et al. 2019. *Vehicle-to-Vehicle Communications Research Project (V2V-CR)*. (Pre-final version). Washington, DC: NHTSA.

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