Pedal Misapplication in Heavy Vehicles

Special Investigation Report

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Safety Board

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Highway Special Investigation Report

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National
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Safety Board

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Abstract: In May 2005, the National Transportation Safety Board (NTSB) began its investigation of a school bus accident that occurred in Liberty, Missouri. During the course of the investigation, information was uncovered that suggested pedal misapplication as a factor in the accident—that is, depressing the accelerator instead of, or in addition to, the brake pedal. The NTSB subsequently investigated four additional accidents—in Falls Township and Newtown, Pennsylvania; Asbury Park, New Jersey; and Nanuet, New York—involving heavy vehicles in which pedal misapplication was determined to be a factor. Despite varying circumstances, these five accidents share common elements. In all five, the drivers either reported a loss of braking or were observed by vehicle occupants to be unsuccessfully attempting to stop the vehicles, though no evidence of braking system failure was found.

Major safety issues identified by this special investigation of pedal misapplication in heavy vehicles include the need for brake transmission shift interlock systems; the need for increased analysis of pedal design configurations; the need for school bus drivers, in particular, to have annual refamiliarization training on all bus types that they might drive; the benefits of positive separation in transit areas to decrease the risks of unintended acceleration during loading and unloading activities; and the need for event data recorders in school buses and motorcoaches. As a result of this investigation, the NTSB makes recommendations to the National Highway Traffic Safety Administration, the National Association of State Directors of Pupil Transportation Services, and the National Association for Pupil Transportation. In addition, the NTSB reiterates and reclassifies two previously issued recommendations to the National Highway Traffic Safety Administration and reclassifies one previously issued recommendation to the Community Transportation Association of America.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transit Association
ABS	antilock braking system
BTSI	brake transmission shift interlock
CAMI	Civil Aerospace Medical Institute
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
CTAA	Community Transportation Association of America
DOT	U.S. Department of Transportation
ECM	electronic control module
ECU	electronic control unit
EDR	event data recorder
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	*Federal Motor Vehicle Safety Standard*
FTA	Federal Transit Administration
GPS	global positioning system
GVWR	gross vehicle weight rating
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
SR	State Route
U.S.C.	*United States Code*

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Introduction

In May 2005, the National Transportation Safety Board (NTSB) began its investigation of a school bus accident that occurred in Liberty, Missouri. During the course of the investigation, information was uncovered that suggested pedal misapplication as a factor in the accident—that is, depressing the accelerator instead of, or in addition to, the brake pedal.

The NTSB subsequently investigated four additional accidents involving heavy vehicles in which pedal misapplication was determined to be a factor. (See appendix A.) Despite varying circumstances, these five accidents share common elements. In all five, the drivers either reported a loss of braking or were observed by vehicle occupants to be unsuccessfully attempting to stop the vehicles, though no evidence of braking system failure was found.

Pedal misapplication is not a new phenomenon. In a 1989 study using light vehicles, the National Highway Traffic Safety Administration (NHTSA) concluded that pedal misapplication is the most probable explanation for sudden acceleration in which no vehicle malfunction is evident; and, in cases where vehicle malfunctions occur, pedal misapplications are often the direct cause of high engine power.[1]

One of the recommendations of the NHTSA study was to install brake transmission shift interlock (BTSI) devices, which require the driver to apply the brakes to shift the transmission out of the "park" position—thus precluding inadvertent and unintentional application of motive power at the time of vehicle startup. As manufacturers began to voluntarily install interlock devices, the occurrences of sudden acceleration sharply decreased. Comparisons of the same model vehicle with and without a BTSI device showed a 60 percent reduction in sudden acceleration complaints for the interlock-equipped model.[2] In July 2006, NHTSA stated that 80 percent of model year 2006 motor vehicles[3] were being equipped with interlock devices. Currently, all model lines appear to be equipped with BTSI devices. The focus of recent legislation[4] is strictly on motor vehicles weighing less than 10,000 pounds. Heavy vehicles are not required to have BTSIs.

Despite the efforts of the NTSB, NHTSA, and others, unintended acceleration incidents attributed to pedal misapplication continue to occur. Such accidents warrant serious attention because they can be so injurious. To date, both the NTSB and NHTSA have focused on passenger cars. However, as the accidents discussed in this report demonstrate, pedal

[1] *An Examination of Sudden Acceleration*, DOT HS 807 367 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1989).

[2] DOT HS 807 367.

[3] NHTSA defined motor vehicles as passenger cars, light trucks, multipurpose vehicles (minivans), and buses produced for the U.S. market with a gross vehicle weight rating (GVWR) up to 10,000 pounds.

[4] Cameron Gulbransen Kids Transportation Safety Act of 2007, H.R. 1216, 110th Congress, 2nd Session (2008).

misapplication can occur in heavy vehicles as well as light vehicles. Any vehicle operated by a driver is susceptible to the loss of control caused by human error.

The NTSB has investigated both light and heavy vehicle sudden acceleration accidents. In 1997, the NTSB investigated a Normandy, Missouri, accident involving a transit bus.[5] The bus driver had just discharged passengers when the bus accelerated into pedestrians, resulting in four fatalities. In 2003, the NTSB investigated an accident in Santa Monica, California, in which a passenger car accelerated into a farmer's market, resulting in 10 fatalities.[6] The Board concluded that pedal misapplication was the probable cause in both of these accidents.

This special investigation report summarizes the NTSB's recent investigative work on unintended acceleration incidents; reviews previous work on pedal misapplication; examines the potential benefits and challenges of BTSI devices, pedal design, positive separation, and event data recorders (EDRs) with respect to pedal misapplication in heavy vehicles; and presents recommendations to prevent or mitigate the consequences of pedal misapplication involving heavy vehicles.

[5] *Bus Collision With Pedestrians, Normandy, Missouri, June 11, 1997*, Highway Accident Summary Report NTSB/HAR-98/01/SUM (Washington, DC: National Transportation Safety Board, 1998).

[6] *Rear-End Collision and Subsequent Vehicle Intrusion Into Pedestrian Space at Certified Farmers' Market, Santa Monica, California, July 16, 2003*, Highway Accident Report NTSB/HAR-04/04 (Washington, DC: National Transportation Safety Board, 2004).

Pedal Misapplication and Unintended Acceleration

NHTSA Activities

The problem of sudden accelerations entered the national spotlight in the mid to late 1980s when NHTSA received a growing number of related complaints against light vehicle manufacturers. These complaints prompted NHTSA to open an investigation into sudden acceleration.

In January 1989, NHTSA released a report on its 2-year investigation.[7] To differentiate between sudden acceleration incidents and other events involving unwanted engine power, such as throttle sticking or engine surging, NHTSA defined sudden acceleration as "unintended, unexpected, high-power accelerations from a stationary position or a very low initial speed accompanied by an apparent loss of braking effectiveness." NHTSA investigators and a panel of outside experts examined the braking and throttle systems of 10 light vehicles with above-average reported rates of sudden acceleration. They considered how engines and their controls might produce unwanted power, how electromagnetic and radio-frequency interference might stimulate engine control malfunctions, the unlikelihood of braking systems failing and spontaneously returning to normal function, and the role of the driver.

Although NHTSA found some mechanical failure modes that could result in sudden acceleration, the overwhelming majority would leave some evidence of system failure—which was not found in the examined vehicles. NHTSA concluded that depressing the accelerator instead of, or in addition to, the brake pedal was the most probable explanation for sudden acceleration when no vehicle malfunction was evident. The NHTSA report suggested several possible factors that might contribute to pedal misapplication, including lateral pedal placement, similar pedal feel, pedal travel and offset (vertical and horizontal), and driver familiarity with the vehicle. NHTSA recommended increasing lateral separation of the pedals, raising the brake pedal, and using BTSI devices.[8]

Investigations completed by other agencies have confirmed NHTSA's findings that most sudden acceleration events are likely pedal misapplications. Transport Canada concluded that sudden acceleration incidents were likely the result of driver error;[9] the Japanese Ministry of Transport found no common mechanical cause for sudden acceleration;[10] and, more recently, in

[7] DOT HS 807 367.

[8] The report used the term "automatic shift-locks."

[9] P. Marrinder and J. Granery, *Investigation of Sudden Acceleration Incidents*, Transport Canada File ASF3282-8-18 (Ottawa, Ontario: Transport Canada, 1988).

[10] *An Investigation on Sudden Starting and/or Acceleration of Vehicles With Automatic Transmissions* (Tokyo: Japanese Ministry of Transport, 1989).

an examination of 12 car models, the Korean Ministry of Construction and Transportation found no sudden accelerations caused by mechanical defects.[11]

Common Risk Factors

A comprehensive examination of the risk factors associated with unintended acceleration also suggests a relationship to human factors.[12] Such incidents were also found to occur most frequently in vehicles with which the driver was unfamiliar.

In a June 1989 article published in *Human Factors*, R. Schmidt reviewed the role of human factors in unintended acceleration.[13,14] As cited in the article, previous examination of accident reports and laboratory data had found foot placement errors—pressing the accelerator instead of the brake, pressing the accelerator and the brake, and slipping from the brake to the accelerator—to be well-documented, though rare, events in both laboratory experiments[15] and normal driving.[16]

According to Schmidt, a driver who depresses the accelerator when he intends to depress the brake has made an error of response execution, which involves selecting an appropriate response but carrying it out inadequately or incorrectly. Examples of this type of error are raising a car window when you wanted to lower it or activating windshield wipers when you intended to signal a turn. In this type of error, the person has chosen the correct response, but its execution leads to an outcome other than the one desired. Within the driving task, the driver correctly chooses to depress the brake, which is accomplished safely most of the time. However, even when this task is successfully executed, there is considerable variation in where on the brake pedal the foot is placed. Occasionally, the variation in foot placement will be so large that the pedal is missed completely; if the foot falls to the right, the driver will depress the accelerator, committing an error of response execution.

[11] Information obtained from a March 29, 2004, Chosun Ilbo article. See <http://english.cpb.or.kr/user/bbs/code02_detail.php?av_jbno=2004032900022&av_pg=792&gubun> (accessed February 21, 2008).

[12] *Engineering Analysis Action Report*, Document EA78-110 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1987).

[13] R. Schmidt, "Unintended Acceleration: A Review of Human Factors Contributions," *Human Factors*, vol. 31, no. 3 (1989), pp. 345–364.

[14] Schmidt refers to sudden acceleration as "unintended acceleration."

[15] (a) S. Rogers and W. Wierwille, "The Occurrence of Accelerator and Brake Pedal Actuation Errors During Simulated Driving," *Human Factors*, vol. 30, no. 1 (1988), pp. 71–81. (b) M. Vernoy and J. Tomerlin, "Pedal Error and Misperceived Centerline in Eight Different Automobiles," *Human Factors*, vol. 31, no. 4 (1989), pp. 369–375.

[16] M. Perel, *Analyzing the Role of Driver/Vehicle Incompatibilities in Accident Causation Using Police Reports*, Technical Report DOT HS 801 858 (Washington, DC: U.S. Department of Transportation, 1976); as cited in Schmidt (1989).

These errors are thought to be the result of variabilities that affect the force and timing of muscle movements, such as distance and speed. Applied to the driving task, they imply that, generally, the further the limb (foot) is from the target (brake) and the faster the movement is made, the greater the variation in final position. Variability in accuracy can also be introduced by factors other than the force and timing of muscle movement, including head and body position,[17] head position and direction of gaze,[18] vision and optical flow,[19] and negative transfer[20] from other vehicles.

Once it is understood how and why a driver's foot might end up on the accelerator instead of the brake, it is important to consider why drivers fail to detect this error. It may at first seem simple for drivers to realize that they are depressing the accelerator instead of the brake and quickly take corrective action. Unfortunately, however, accidents such as the one in Santa Monica have demonstrated that unintended acceleration can continue for several seconds, well beyond the time required to execute corrective action. For the error in response execution to produce unintended acceleration events of longer duration, something would have to interfere with the driver's ability to recognize and correct the error.

Several factors come into play that may prevent drivers from realizing pedal misapplications. Typically, when a driver moves her foot from the accelerator to the brake, she relies on muscle memory to confirm that the intended action has been accomplished. The accuracy of the movement may not be communicated except in cases when a pedal is missed. When a pedal misapplication occurs, a driver's attention is likely to focus outside the vehicle because of the need to avoid obstacles. The theory of perceptual narrowing postulates that a person under stress focuses on one cue and misses others. This shrinkage of the attention field is thought of as a reduction in the ability to deal with peripheral cues in favor of more central events. Perceptual narrowing applies not only to visual cues but also to all sensory modalities (hearing, smell, touch, and taste).

Further limiting attention during an unintended acceleration incident is the driver's stress level. Studies have shown that people under extreme stress often exhibit *hypervigilance*, commonly known as panic,[21] which is one possible explanation for the persistence of pedal misapplication. Hypervigilant states can temporarily impair cognitive function and decision

[17] (a) J. Nacson and R. Schmidt, "The Activity-Set Hypothesis for Warm-up Decrement," *Journal of Motor Behavior*, vol. 3 (1971), pp. 1–15; as cited in Schmidt (1989). (b) R. Pepper and L. Herman, "Decay and Interference Effects in the Short-Term Retention of a Discrete Motor Act," *Journal of Experimental Psychology Monographs*, vol. 83 (1970); as cited in Schmidt (1989).

[18] R. Roll, C. Bard, and J. Paillard, "Head Orienting Contributes to the Directional Accuracy of Aiming at Distant Targets," *Human Movement Science*, vol. 5 (1986), pp. 359–371; as cited in Schmidt (1989).

[19] D. Lee and D. Young, "Visual Timing of Interceptive Action," eds. D. Ingle, M. Jeannerod, and D. Lee, *Brain Mechanisms and Spatial Vision* (Dordrecht: Martinus Nijhoff, 1985), pp. 1–30; as cited in Schmidt (1989).

[20] Negative transfer is the interference of previously learned knowledge or behavior in the process of learning something new or performing a new task. An example in a vehicle would be "learning" where the pedals are in your car, then buying a new car with pedals in a different position.

[21] I. Janis, P. Defares, and P. Grossman, "Hypervigilant Reactions to Threat," *Selye's Guide to Stress Research* (New York: Van Nostrand Reinhold, 1983), pp. 1–43.

making. The panicked person will tightly focus on the moment and may experience a loss of memory capacity, engage in simplistic thinking, have disrupted motor control, or experience strong emotions or a lack of emotion.[22]

A hypervigilant state is thought to involve three components: a strong, startling stimulus; perception of the stimulus as life threatening; and significant pressure to quickly find a solution.[23] All three components are present during pedal misapplication:

- The unexpected acceleration is the stimulus.
- The apparently out-of-control vehicle threatens the life of the driver, other motorists, or pedestrians.
- The vehicle's increasing speed imposes a significant urgency for driver response.

Once in a hypervigilant state, the driver may "freeze"; may not remove his foot from the accelerator because he "knows" it is on the brake; and may not be able to conceptualize and implement other solutions, such as shifting to neutral or turning off the vehicle. In short, the driver becomes confused.

To summarize, the majority of organizational efforts to understand unintended acceleration have concluded that these events typically do not have a mechanical cause. Rather, the origins of unintended acceleration are found in human error—specifically, pedal misapplication.[24] Although the exact mechanism of the error is not completely understood, researchers believe that the movement of the leg and foot, the position of the body, visual cues, previous experience, and the brain's response to stress all play a role. Regardless of the mechanism, pedal misapplication remains the most likely reason for unintended acceleration events where no mechanical cause can be found.

[22] Schmidt (1989), pp. 360–361.

[23] I. Janis and L. Mann, *Decision-making. A Psychological Analysis of Conflict, Choice, and Commitment* (New York: Free Press, 1977).

[24] (a) DOT HS 807 367. (b) Marrinder and Granery (1988). (c) Japanese Ministry of Transport (1989).

Subject Accidents

Since May 2005, the NTSB has investigated five accidents involving heavy vehicles in which pedal misapplication was a factor. These accidents resulted in two fatalities and 71 injuries. (See table 1.)

Table 1. Accidents and injury data from pedal misapplication investigations, 2005–2008.

	Injuries[a]			
Accidents	**Fatal**	**Serious**	**Minor**	**None**
Liberty, Missouri	2	13	36	5
Falls Township, Pennsylvania	0	1	21	7
Asbury Park, New Jersey	0	0	0	1
Nanuet, New York	0	1	0	0
Newtown, Pennsylvania	0	0	0	13
Total	2	14	57	26

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

Liberty, Missouri, Investigative Facts

Accident Narrative

On May 9, 2005, about 8:19 a.m., a 2000 Thomas Built 84-passenger school bus, with a 45-year-old driver and 53 elementary school-aged children on board, was traveling southbound on State Route (SR) 291, approaching the intersection with SR 152, near Liberty, Missouri. (See figure 1.) The weather was clear, and the roadway was dry. The speed limit was 45 mph, dropping to 40 mph on the descending grade to the intersection. Approximately 0.5 mile prior to the intersection of SR 291 and SR 152, the bus was traveling at a global positioning system (GPS)-reported speed of 49 mph.[25]

[25] The GPS device was used by the school district for fleet management and routing and was not accessible for driver use. Due to limitations in the GPS data, 49 mph was the last recorded speed of the bus.

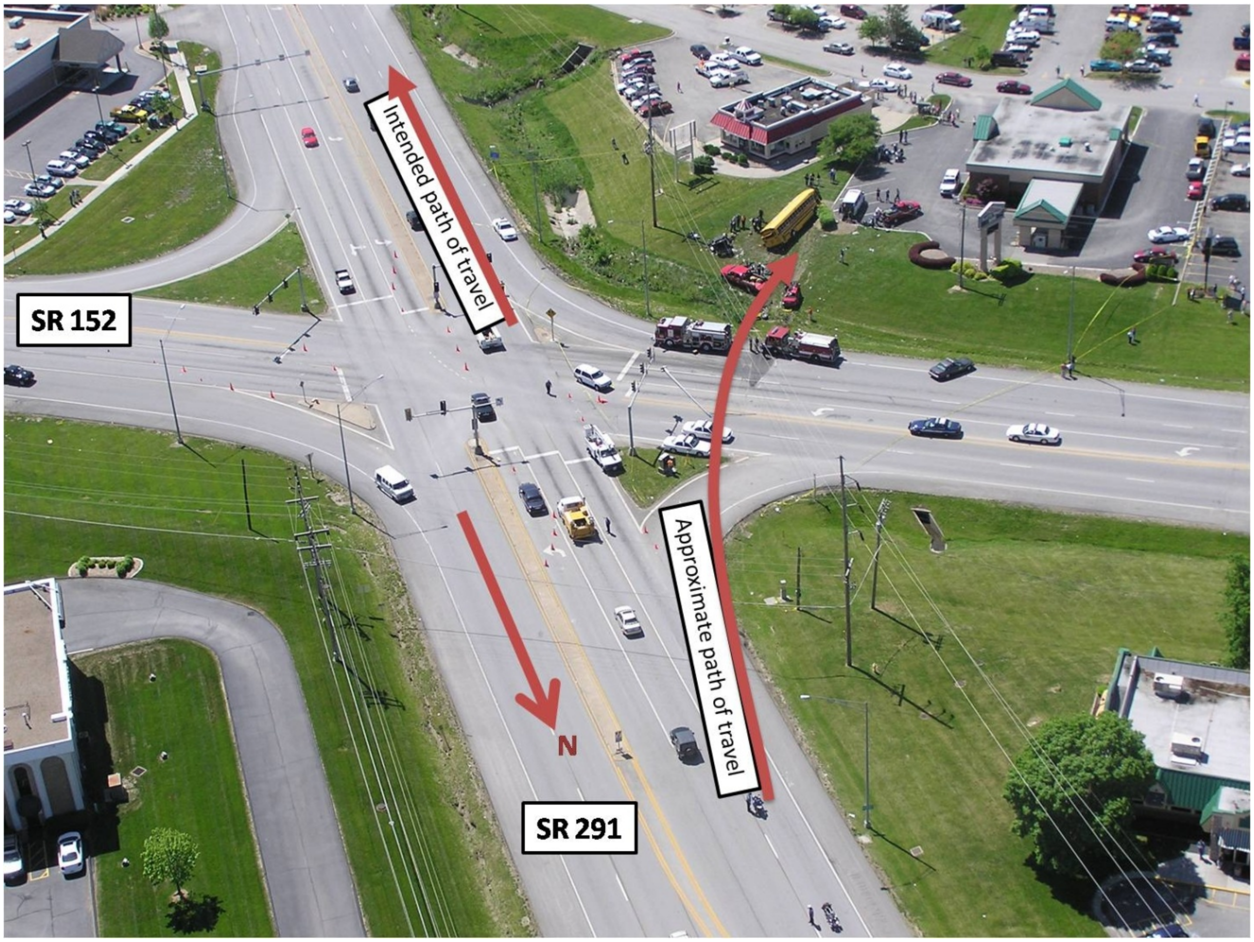

Figure 1. Liberty, Missouri, accident location and vehicle path. (Courtesy of Missouri State Highway Patrol)

In an initial statement to the Liberty Police Department, the school bus driver reported that traffic was beginning to back up as she reached the top of the hill on SR 291. She stated that the bus seemed to pick up speed as she stepped on the brake pedal, and she believed that she tried to steer the bus toward the shoulder. In this statement, the driver stated that she did not think she had her foot on the accelerator; in later statements, she indicated that she definitely had her foot on the brake and not on the accelerator.

The bus eventually moved to the right shoulder and struck a light pole, continuing south through a right-turn-only lane, crossing the westbound lanes of SR 152, and entering the eastbound lanes. A 2003 Lincoln LS, with a 49-year-old driver, was stopped in the left lane of eastbound SR 152; and a 2001 GMC pickup truck, with a 53-year-old driver, was stopped in the right lane, adjacent to the Lincoln. The school bus struck the Lincoln on the driver's side, pushing it into the GMC. The three vehicles moved together in a southerly direction into a drainage ditch at the southwest corner of the intersection. The collision resulted in fatal injuries to both the Lincoln and the GMC drivers. Forty-eight children and the bus driver were injured.

Accident Trip

At the time of the accident, the bus was operating on school route 449, which began at the transportation lot and ended at Ridgeview Elementary School. This route covered 12.4 miles and consisted of 20 designated stops for the transportation of 76 elementary school children. The subject run was scheduled to begin at 7:42 a.m. and end at 8:25 a.m. The accident trip was the second trip of the day for the bus driver; her first trip was scheduled from 6:47–7:25 a.m. and involved the transportation of students to Liberty Senior High School.

The bus being operated and the route being driven were the usual ones assigned to the accident driver. When interviewed, the 9-year-old students on the bus at the time of the accident indicated that it was a typical day; they noted nothing unusual in the driver's performance, behavior, or demeanor. According to the students, the first sign of a problem was when they noticed that the bus was traveling much faster than normal. The interviewed students indicated no disturbances on the bus that would have been a source of distraction to the driver.

Eyewitnesses to the accident, both on the school bus and in other vehicles, stated that the bus was traveling at a high rate of speed, even before it began to descend the hill approaching the intersection. One witness and one student reported hearing louder-than-normal engine sounds. The witnesses indicated that, as the bus approached the intersection, the driver executed a series of evasive steering maneuvers to avoid slower moving traffic and stopped vehicles.

School Bus Mechanical Inspection

The accident vehicle—a model H, SAF-T Liner, 84-passenger, rear-engine, transit-style[26] school bus—was manufactured by Thomas Built Buses in High Point, North Carolina, in April 1999. It had an Allison automatic transmission and Bendix antilock braking system (ABS) airbrakes and was equipped with a Cummins six-cylinder diesel engine with an electronic control module (ECM). The ECM was not designed to record collision-related information; the bus was not equipped with an EDR.[27]

Following the accident, the Missouri State Highway Patrol inspected the school bus on scene. The bus was subsequently transported to a Clay County Highway Department maintenance facility, where NTSB investigators examined and tested the conventional airbrake system, ABS, pedals, and steering. No mechanical defects, other than accident-related damage, were found. For details of the mechanical inspection, see appendix B.

[26] A transit-style or "type D" school bus consists of a body installed on a chassis, with the engine mounted in the front, midsection, or rear. These vehicles have a GVWR in excess of 10,000 pounds and are designed for carrying more than 10 passengers. The entrance door and driver's seat are located forward of the front axle.

[27] An EDR is a device designed to record vehicle operating and status information and, in the event of a crash, to store that information for later retrieval. For a more detailed description, see "Highway Vehicle Event Data Recorders" later in this report, under the discussion of "Countermeasures and Mitigation."

Driver Information

Certification and Experience. At the time of the accident, the bus driver held a valid Missouri class B commercial driver's license (CDL), with "M" and "P" endorsements and an "A" restriction.[28] She also held a Missouri school bus operator's permit[29] valid through July 2007; the medical certificate for the permit was to expire in June 2005. The driver had been employed by Liberty Public Schools since July 1998, following completion of initial training from the Liberty school district and receipt of her CDL. The accident driver had attended required annual safety meetings and refresher training from 1998–2005.

After her initial statement to police following the accident, the driver, through her attorney, declined to be interviewed by NTSB investigators, insisting that the brakes failed as the bus proceeded down the descending grade on approach to the intersection.

Toxicology and General Health. Postaccident testing conducted on the driver by the State of Missouri and the U.S. Department of Transportation (DOT) Civil Aerospace Medical Institute (CAMI) was negative for alcohol and common illicit or performance-impairing drugs.[30] The driver's annual CDL medical examination records indicated that she was under treatment for hypertension and was taking two prescription medications for the condition, but no other health issues were indicated. A full 72-hour history was not compiled because the driver declined to speak with NTSB investigators.

Training. The Liberty school district requires all bus driver applicants to successfully complete operational school bus training with a driver trainer and the transportation supervisor. The applicant can then apply for a Missouri CDL learner's permit, after which 8–10 hours of supervised driving is required. According to the accident driver's qualification file, she completed 18.5 hours of behind-the-wheel training and 22.5 hours of classroom instruction in June 1998. In August 2003, the driver completed 3 hours of behind-the-wheel training for transit buses and 2 hours of training on transporting wheelchair-bound students. From 1998–2005, she attended annual orientation training in August (24 hours of classroom and skills combined) and at least 5 monthly training meetings each school year.

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[28] A class B CDL allows operation of any single vehicle with a GVWR of at least 26,001 pounds or any such vehicle towing a vehicle not in excess of 10,000 pounds GVWR. Holders of a class B license may also, with appropriate endorsements, operate all vehicles within class C. The "M" endorsement allows the operation of a motorcycle; the "P" endorsement allows the operation of a vehicle designed to carry 16 or more persons, including the driver; and the "A" restriction requires the use of corrective lenses.

[29] Prior to September 30, 2005, a Missouri school bus operator's permit was required to transport school children in grades 12 or below for a public, private, or religious school, including nursery schools, if the vehicle used was either a yellow school bus or any other approved vehicle owned or operated by a school or religious institution and used for this purpose over a regularly scheduled route. After September 30, 2005, the Missouri school bus operator's permit was replaced by the "S" endorsement as required by the Motor Carrier Safety Improvement Act.

[30] Substances tested for were amphetamines, opiates, marijuana and its metabolites, cocaine and its metabolites, phencyclidine, propoxyphene, benzodiazepines, barbiturates, methadone, antidepressants, meprobamate, methaqualone, and nicotine.

Road Testing

A representative of the Liberty Police Department drove an exemplar bus along the route followed by the accident bus. At a speed of 50 mph, with no accelerator or brake input, the exemplar bus slowed to 47 mph at the point where the accident bus departed the roadway. When traveling 50–55 mph down a grade similar to that at the accident location, the exemplar bus could be brought to a stop under full brake/full accelerator pedal application. These tests demonstrated that even with no driver input, the bus should have slowed; and with simultaneous brake and accelerator application, the bus should have slowed as well.

Liberty Analysis

The NTSB investigation revealed that the Liberty bus driver was properly licensed, had completed all required initial and refresher training, and was not under the influence of illicit or other performance-impairing drugs. Therefore, the NTSB concludes that neither the licensing nor the training of the Liberty driver contributed to the accident, and that neither drugs nor alcohol impaired the driver's performance.

A thorough postaccident examination of the school bus indicated that the braking system was functioning normally at the time of the accident; all the vehicle's brakes were found to be within adjustment. The accelerator was physically and electronically tested and was found to be operating normally. Road testing performed with an exemplar bus revealed that—upon full application of both the brake and the accelerator—the vehicle could be brought to a stop under speed and grade conditions similar to those in the accident, which is consistent with the fact that these vehicles are designed such that the braking system can overcome the engine's horsepower. No evidence was found to suggest that the mechanical, electrical, or pneumatic (air) systems of the school bus had failed or otherwise malfunctioned during the accident sequence. Therefore, the NTSB concludes that the Liberty accident cannot be attributed to a mechanical failure of the school bus.

The Liberty bus driver reported losing braking ability, indicating that the vehicle would not stop when she applied the brakes. Based on the postaccident inspection and testing performed by NTSB investigators, such an event seems unlikely. However, the driver's statement is consistent with pedal misapplication; she genuinely believed she was depressing the brake and experiencing brake failure. In addition—though reasons for the initial pedal misapplication cannot be explored because the driver declined to speak to investigators—the following factors are all in harmony with the model of an unintended acceleration incident resulting from pedal misapplication:

- Apparent loss of braking,
- Increasing speed of the bus,
- Wide-open throttle heard by witnesses, and

- Stressful situation of approaching an intersection and stopped traffic while apparently out of control.

The NTSB, therefore, concludes that the circumstances of the Liberty accident are consistent with driver pedal misapplication.

Falls Township, Pennsylvania, Investigative Facts

Accident Narrative

On January 12, 2007, about 2:30 p.m., a 1995 Thomas Built 78-passenger school bus was one of several buses parked side by side in the parking lot of the Pennsbury High School east campus in Falls Township, Pennsylvania. According to the 54-year-old driver, after loading 10 students, he put his foot on the brake pedal and started the bus. As the bus to the left departed, he placed his hand on the parking brake and heard what he described as an engine racing behind him. The driver released the parking brake and the bus began to move, despite the fact that—according to the driver—his foot was on the brake. The bus struck the side mirror on an adjacent bus, traversed 23 feet, mounted the curb, and began striking students who were standing on the sidewalk. The bus traveled 25 feet on the sidewalk, striking 18 student pedestrians. According to the driver, he was "hitting the brake harder and harder." As the bus began to strike pedestrians, the driver pulled the parking brake but to no effect. The driver stated that he also attempted to shift the bus into another gear, again with no effect, and then steered the vehicle onto the roadway.

As the bus gathered speed and continued across the east campus parking lot and an access road leading to the west campus, the driver stated that he steered the side of the bus into a guardrail in an effort to slow the vehicle while continuing to depress the brake pedal. As the bus continued forward, the driver steered toward a chain-link fence. Finally, observing traffic ahead, he steered the bus to the right, into a concrete block retaining wall, bringing the vehicle to a stop. (See figure 2.) The collision resulted in serious injuries to 1 pedestrian and minor injuries to 17 pedestrians, 3 school bus passengers, and the bus driver.

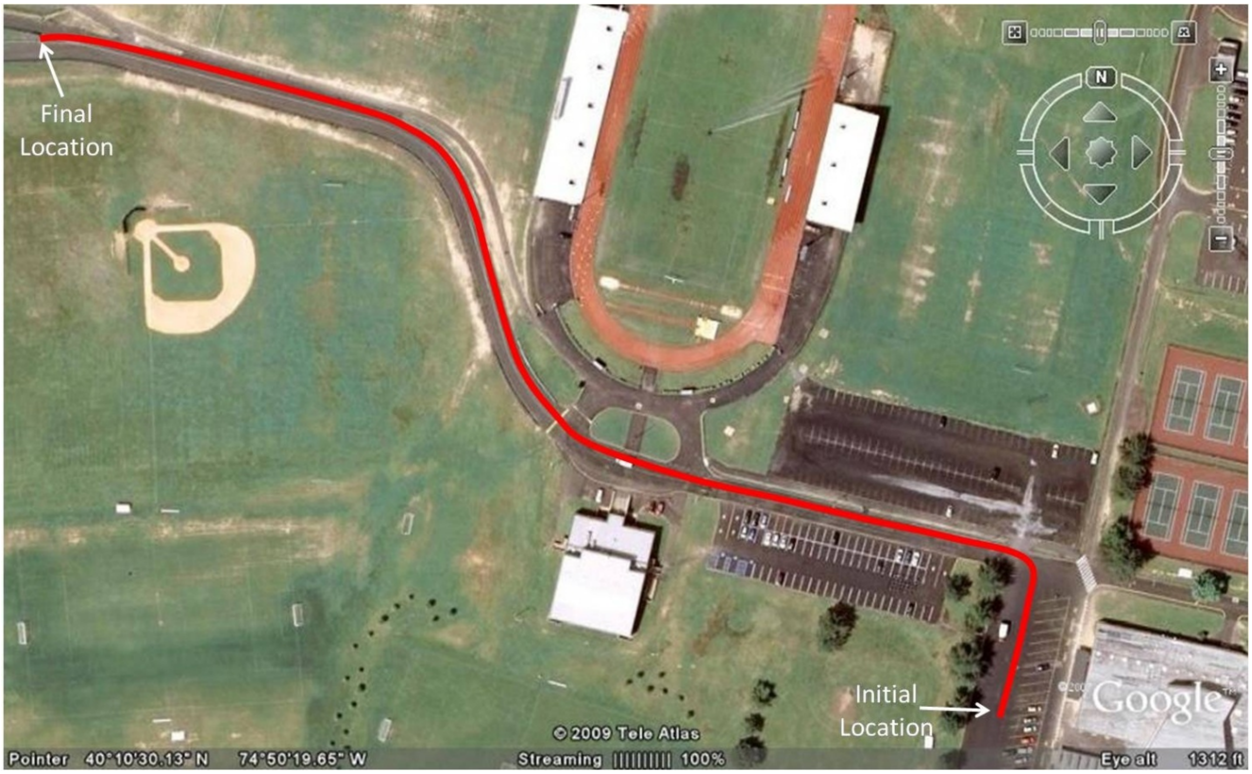

Figure 2. Falls Township, Pennsylvania, accident location and vehicle path. (Courtesy of Google Earth)

Accident Trip

According to the school bus driver, his typical day consisted of starting work about 6:50 a.m., completing his first run of the day by 8:45 a.m., and returning home by 9:00 a.m. From 12:40–1:00 p.m., he drove the bus as a shuttle on the high school campus. He reported back to the high school by 2:05 p.m. and began his last run of the day at 2:15 p.m.

On the day of the accident, the driver used a replacement bus to complete his usual runs for the middle school, the elementary school, and a 12:40 p.m. shuttle run at the high school. He returned to the high school about 2:00 p.m. and parked the bus in a designated space on the east campus parking lot, alongside several other buses. He remained parked while students boarded the buses. The accident occurred as the driver departed the high school on the afternoon run.

School Bus Mechanical Inspection

The accident vehicle—a model MVP, SAF-T Liner, 78-passenger, rear-engine, transit-style school bus—was manufactured by Thomas Built Buses in High Point, North Carolina, in May 1994. The bus had an Allison automatic transmission and was equipped with a Cummins six-cylinder diesel engine. It was not equipped with an ABS, ECM, or EDR.

Following the accident, NTSB investigators inspected the school bus, including the braking system, throttle, steering system, and brake lights. No mechanical defects, other than accident-related damage, were found. For details on the mechanical inspection, see appendix C.

The accident bus was a replacement bus. The driver's normally assigned bus—a 1998 AmTran, front-engine, transit-style school bus—had been removed from service the day before for maintenance. For a detailed discussion of the differences in the pedal configurations of the driver's usual and replacement buses, see "Pedal Design Investigation" later in this report.

Driver Information

Certification and Experience. At the time of the accident, the driver held a valid Pennsylvania class B CDL, with "P" and "S" endorsements, issued in June 2006 and expiring in June 2010.[31] He held a valid 1-year medical certificate issued in February 2006, and a Pennsylvania school bus endorsement card[32] issued in May 2006 and valid through June 2007. He had been employed by the Pennsbury School District since June 2000. School district records indicate that he had completed the 20-hour initial certification training course required by the Pennsylvania Department of Transportation as well as periodic recertification training.

Following the accident, the driver was interviewed by NTSB investigators. He stated that he felt resistance when he pressed the brake pedal, but that the pedal felt normal to him otherwise—except for the bus failing to stop. He also stated that when he pressed the pedal, it went to the floor; and he went on to say that this behavior was usual for air brakes.

Toxicology and General Health. Within 2 hours of the accident, blood and urine samples were taken from the driver. Postaccident testing of the samples by CAMI was negative for alcohol and common illicit or performance-impairing drugs.[33]

Falls Township Analysis

NTSB investigators determined that the Falls Township bus driver was properly licensed and had completed all required initial and refresher training. During the accident sequence, he was able to recognize the danger, determine a course of action, and implement a response. No performance-impairing drugs were found in his system following the accident. Therefore, the

[31] The "P" endorsement allows the operation of a vehicle designed to carry 16 passengers or more, including the driver; and the "S" endorsement is required to drive a school bus designed to carry 11 passengers or more, including the driver. For additional information on the class B CDL, see footnote 28 in the Liberty discussion.

[32] In Pennsylvania, three credentials are required to operate a school bus: a valid CDL with an "S" endorsement, a valid school bus endorsement card, and a valid physician's certificate. The school bus endorsement card is reissued annually if the requirement for an annual physical examination is met.

[33] Substances tested for were amphetamines, opiates, marijuana and its metabolites, cocaine and its metabolites, phencyclidine, propoxyphene, benzodiazepines, barbiturates, methadone, antidepressants, meprobamate, methaqualone, and nicotine.

NTSB concludes that neither the licensing nor the training of the Falls Township driver was a factor in the accident, and that neither drugs nor alcohol impaired the driver's performance.

Postaccident inspection of the vehicle's braking system indicated that it was working properly at the time of the accident. When accident-related damage was repaired, the accelerator pedal and throttle linkage performed normally. Similarly, the steering system was found to be in good working order. The driver's description of the behavior of the pedal he was depressing and the parking brake is consistent with their normal operation. Therefore, the NTSB concludes that the Falls Township accident cannot be attributed to a mechanical failure of the school bus.

According to the driver, he depressed the brake and started the bus as he initiated departure from the high school. When he released the parking brake, the bus moved, striking another bus and several students on the sidewalk. Although the driver was, in his words, "hitting the brake harder and harder," the bus continued across the school campus. The driver steered the bus into a W-beam guardrail and a concrete block wall before the vehicle came to a stop, still under acceleration. In all, the bus traveled more than 1,800 feet. As described earlier in this report, a driver's belief that he is depressing the brake despite continuing acceleration is consistent with pedal misapplication.

The driver mentioned hearing an engine revving behind him as he prepared to release the parking brake. In the driver's usual bus, the engine is at the front of the vehicle; in the accident bus, the engine is at the rear. Although buses parked next to the accident bus could have been the source of the engine sounds, the revving is consistent with the driver's own vehicle engine being under acceleration. Just prior to hearing the revving, the driver placed his foot on what he believed was the brake, though having his foot on the accelerator would produce the sound he heard and would be consistent with the timing of the noise. The driver also stated that he felt resistance in the brake pedal and that it went to the floor—a description consistent with applying the accelerator. The accelerator going to the floor would produce both the revving noise heard by the driver and the acceleration necessary to move the bus more than 1,800 feet.

The bus driver suffered right foot injuries from accident deformation in the pedal area. Figure 3 shows this deformation in the foot well of the accident bus, just above the location of the accelerator pedal. The assertion of the Falls Township school bus driver that he was depressing the brake; the revving noise he heard; the lack of a mechanical defect on the bus; his report of feeling resistance when depressing the brake pedal; and his foot injury, apparently resulting from the foot well deformation, all provide evidence that the accelerator was being depressed. Therefore, the NTSB concludes that the circumstances of the Falls Township accident are consistent with driver pedal misapplication.

Figure 3. Accident damage in foot well of Falls Township school bus.

It is also noteworthy that the accident bus was not the driver's usual front-engine bus. The replacement bus had a rear-engine configuration and was equipped with pedals of different sizes, heights, and separation than his usual bus. As described above, unfamiliarity with a vehicle has been linked to a higher frequency of pedal misapplication and unintended acceleration. The difference in engine location led the driver to misidentify the revving engine he heard as belonging to another bus instead of the one he was driving. The NTSB concludes that the Falls Township driver's unfamiliarity with the school bus contributed to the occurrence of pedal misapplication.

Other Investigations

In addition to the Liberty and Falls Township investigations, the NTSB also gathered data on specific issues related to pedal misapplication from three additional heavy vehicle accidents.

Asbury Park, New Jersey

On November 22, 2006, about 1:12 p.m., a 33-year-old firefighter crashed a 2006 HME fire truck into the bay door of the firehouse located in Asbury Park, New Jersey. Damages to the fire truck and to the firehouse were estimated at $30,000 each. No injuries were sustained as a result of this accident.

The driver stated that he had just parked and exited the fire truck when he decided to move it forward a few feet to facilitate foot traffic behind the vehicle. He stated that he started the truck, put the transmission into "drive," and noticed the engine revving. He went on to say that he released the parking brake with his foot on the service brake, but the service brake did not hold the truck. The fire truck proceeded forward into and partially through the closed bay door.

The accident driver held a valid New Jersey operator's license. He was not required to have either a CDL or a medical certificate. He had almost 10 years of experience driving a variety of fire and rescue equipment but had operated the newly purchased fire truck only a few months.

Following the accident, a representative of the manufacturer inspected the fire truck and found no mechanical malfunctions or defects; nothing was identified that would have caused the vehicle to spontaneously accelerate without driver input.

Nanuet, New York

On January 12, 2007, about 6:50 a.m., a 1995 Blue Bird 65-passenger, conventional-style school bus,[34] occupied solely by a 35-year-old driver, was traveling along the Garden State Parkway (SR 444) in Nanuet, New York, en route to the first pickup of the morning. The driver left the parkway at exit 14-1, Old Nyack Turnpike. As she approached the intersection of Old Nyack Turnpike and South Pascack Road, she failed to make the left turn onto South Pascack Road, continued through the intersection, and crashed the bus into a concrete and metal bridge railing above Pascack Creek. The driver was seriously injured.

The engine compartment and front axle of the bus were destroyed as a result of impact with the bridge railing. Sections of the engine and engine compartment components encroached into the driver's seat area and prevented the front brakes from being examined. The New York State Department of Transportation examined the rear brakes and found them to be in good condition and within adjustment limits. The remainder of the physical examination revealed no apparent defects that would have affected control or handling of the bus.

The accident driver's usual bus—a 2004 International conventional-style school bus—had been brought into the repair shop for a transmission leak on January 11, the day prior to the accident. The driver had been assigned a replacement bus; the accident trip was her first time driving this particular bus on a scheduled run. When interviewed by police, the driver stated that the brakes on the accident bus had failed.

[34] A conventional or type C school bus is designed to carry more than 10 passengers and consists of a body installed on a flat-back cowl chassis with a GVWR of more than 10,000 pounds. The engine is located forward of the windshield; the entrance door and driver's seat are located aft of the front axle.

The pedals for her usual bus were different from those in the accident bus. In her usual bus, the accelerator was set back from the brake, relative to the driver; in the accident bus, the accelerator and brake were located on the same plane.

Newtown, Pennsylvania

On February 11, 2008, about 3:20 p.m., a 1995 Thomas Built 78-passenger school bus was parked parallel to the curb in the parking lot of the Newtown Friends School, in Newtown, Pennsylvania. After loading 12 students, the 61-year-old driver reported that as he placed the bus in gear and released the parking brake, the bus suddenly accelerated. The school bus traveled 98 feet across the parking lot, bypassing the exit. The driver explained that he steered the bus toward an opening between a stopped car and a school staff member directing traffic and ascended a 5-inch-high curb onto a grassy area. The bus then traveled about 44 feet across the grassy area before the driver turned right onto an adjacent access road. The driver reported shifting into reverse, and the vehicle came to a stop on the access road, having traveled a total of 633 feet. This incident resulted in no damage or injuries.

NTSB investigators inspected the vehicle's service brakes, parking brakes, engine, and transmission controls. No evidence of defect or deficiency was found. Dynamic testing of the school bus demonstrated that the service brakes were capable of bringing the vehicle to a stop from 45 mph under full brake/accelerator application.

Other Investigations Summary

The Asbury Park, Nanuet, and Newtown accidents share common elements with the Liberty and Falls Township accidents. In the Asbury Park accident, the driver got into the fire truck to move it slightly forward and noticed that it was revving. When he shifted into drive, the truck accelerated and crashed partially through the bay door. Although the firefighter stated that he had his foot on the service brake, a manufacturer's representative found no mechanical malfunctions or defects upon examining the vehicle after the accident. The driver's description of the vehicle revving is similar to the report of the Falls Township driver, as is the finding of no apparent mechanical cause after the fact.

The school bus driver in the Nanuet accident reported that the brakes on the bus had failed, as also reported by the Liberty accident driver. In both cases, a postaccident inspection found no apparent mechanical cause. Also, both the Nanuet and Falls Township accidents involved replacement or substitute vehicles, with which the drivers would have been less familiar.

In Newtown, as in Falls Township, the accident occurred after the driver shifted the school bus into gear and released the parking brake, and the vehicle traveled a significant distance. As with all of the accidents discussed in this report, no apparent mechanical cause was found after the fact.

The Asbury Park, Nanuet, and Newtown accidents were consistent with episodes of unintended acceleration in that the drivers believed they were depressing the brakes; the brakes were apparently unable to slow, stop, or hold the vehicles; and no mechanical defects were found postaccident. Therefore, the NTSB concludes that pedal misapplication was the initiating event in the accidents in Asbury Park, Nanuet, and Newtown.

Countermeasures and Mitigation

Although pedal misapplication in cars and light vehicles has been studied for 20 years, no similar level of analysis has focused on heavy vehicles. Given the size of heavy vehicles, their cargoes, and their potential to cause injury, it is in the best interest of the traveling public to examine potential countermeasures to pedal misapplication and to find ways of mitigating the effects of unintended acceleration. The remainder of this report examines BTSI devices and pedal design, which can be effective in preventing pedal misapplication; positive separation, which can reduce the incidence of injury to pedestrians and bus passengers; and highway vehicle EDRs, which can definitively establish the role of pedal misapplication in accidents.

Brake Transmission Shift Interlocks

A BTSI device requires a driver to depress the brake pedal to shift an automatic transmission out of the "park" position.[35] Such interlock systems gained popularity following the widespread reporting of sudden automotive acceleration events in the 1980s. BTSI devices have a significant effect on sudden acceleration incidents; comparisons of accident or complaint data between vehicle models with and without BTSIs indicate that interlock systems result in a dramatically lower rate of sudden acceleration. For example, a NHTSA comparison of sudden acceleration incidents for three automobile models indicated much lower rates for the models equipped with interlocks: 1.7 vs. 16.6 per 100,000 cars for the Ford Aerostar, 4.1 vs. 15.0 per 100,000 cars for the Lincoln Town Car, and 2.9 vs. 17.3 per 100,000 cars for the Ford Thunderbird/Cougar.[36]

Three of the accidents discussed in this report—Falls Township, Asbury Park, and Newtown—involved vehicles that began the accident sequence in a parked position. In the Falls Township accident, for example, the school bus driver depressed what he thought was the brake and engaged the transmission; however, the engine revving and the response of the vehicle indicate that he was, in fact, depressing the accelerator. Because a BTSI device requires the driver to have a foot on the service brake prior to engaging the transmission, it would likely have prevented the pedal misapplication that initiated the unintended acceleration. Accordingly, the NTSB concludes that a BTSI device would have prevented the accidents in Falls Township, Asbury Park, and Newtown.

The installation of BTSIs in passenger vehicles sold in the United States is strictly voluntary. Each manufacturer determines whether an interlock system is offered as standard, optional, or not at all on a particular model and year of vehicle. By contrast, Canada has required

[35] Due to the necessity of clutch application before the transfer of engine power to the transmission, pedal misapplication associated with unintended acceleration is not an issue in manual transmission vehicles starting from a parked position. Therefore, a large segment of commercial vehicles are not susceptible to this event.

[36] U.S. Department of Transportation, National Highway Traffic Safety Administration, "Denial of Motor Vehicle Defect Petition, DP99-004," *Federal Register*, vol. 65, no. 83 (April 28, 2000), pp. 25026–25037.

such systems since 2003.[37,38] In July 2006, 19 automobile manufacturers[39] joined with NHTSA in a voluntary commitment to reduce the risk of inadvertent shift selector movement in automatic transmission-equipped light vehicles.[40] At that time, it was estimated that 80 percent of 2006 model year vehicles[41] were equipped with BTSIs and that 98 percent of 2009 model year vehicles would be so equipped.

Under the terms of the voluntary commitment,[42] the manufacturers agreed to the following:

- By September 1, 2010, vehicles with a GVWR up to 10,000 pounds, equipped with an automatic transmission with a "park" position, will have a system that requires the service brake to be depressed before the transmission can be shifted out of "park."
- The system will function in any key position in which the transmission can be shifted out of "park."
- Beginning on September 1, 2006, and on each September 1 thereafter through 2010, participating manufacturers will publicly disclose, at least annually, the models for the upcoming year that will be equipped with a BTSI system.
- Within the same dates, participating manufacturers will provide a statement to NHTSA affirming that the models so identified have been designed with BTSIs.
- Beginning on November 1, 2007, and on each November 1 thereafter through 2011, participating manufacturers will publicly disclose the percentages of their total production for the preceding 12-month period ending August 31 engineered in accordance with the BTSI performance criteria.

Aspects of the voluntary agreement were given the force of law when the Cameron Gulbransen Kids Transportation Safety Act of 2007 was signed on February 28, 2008.[43,44]

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37 In fact, the Canadian Motor Vehicle Safety Standards go further, requiring interlock functionality on all light vehicles, including brake shift interlocks on vehicles equipped with automatic transmissions and clutch interlocks on those equipped with manual transmissions.

38 See <http://canadagazette.gc.ca/partII/2003/20030618/html/sor189-e.html> (accessed February 26, 2008).

39 The manufacturers are Aston Martin, BMW Group, DaimlerChrysler Corporation, Ferrari, Ford Motor Company, General Motors, Honda, Hyundai Motor America, Isuzu Motors, Kia Motors, Maserati, Mazda, Mitsubishi Motors, Nissan, Porsche, Subaru, Suzuki, Toyota, and Volkswagen Group.

40 Although reducing risk was the stated goal of the voluntary commitment, as described earlier in this report, BTSI devices also dramatically reduce the occurrence of sudden acceleration incidents.

41 NHTSA defines these vehicles as passenger cars, light trucks, multipurpose vehicles, and buses with a GVWR up to 10,000 pounds, produced for the U.S. market.

42 *Reducing the Risk of Inadvertent Automatic Transmission Shift Selector Movement and Unintended Vehicle Movement: A Commitment for Continued Action by Leading Automakers* (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 2006).

43 The legislation passed the U.S. House of Representatives in December 2007.

44 "President Bush Signs H.R. 1216 and H.R. 5270 Into Law," available from <http://www.whitehouse.gov/news/releases/2008/02/20080228-4.html>, March 4, 2008.

Among other things, the act requires vehicles to have "rolling away" prevention, which involves the use of BTSI systems. Each motor vehicle with an automatic transmission that includes a "park" position, manufactured for sale after September 1, 2010, must be equipped with an interlock device that requires the service brake to be depressed before the transmission can be shifted out of "park." Furthermore, the interlock device must function in any starting key position in which the transmission can be shifted out of "park." The legislation also incorporates other components of the voluntary agreement, such as the disclosure of BTSI-equipped models. The act is intended to increase safety by reducing inadvertent shift selector movement, but it also will increase safety by requiring a safety device that has been demonstrated to reduce unintended acceleration.

Although the Kids Transportation Safety Act offers a significant improvement in safety for some vehicles, it would not prevent the accidents discussed in this report because it excludes "any motor vehicle that is rated at more than 10,000 pounds gross vehicular weight."[45] However, because the driver is both the source and the means of pedal misapplication—in either light or heavy vehicles—it is reasonable to expect that a safety device that works for one class (light) would work for the other (heavy).[46] Given the demonstrated benefits of BTSI systems in passenger cars and the fact that the mechanisms that cause pedal misapplications are dependent on the human driver and are, therefore, similar in both light and heavy vehicles, the NTSB concludes that requiring interlock devices in heavy vehicles susceptible to pedal misapplication would provide a safety benefit by reducing such instances and unintended acceleration. Accordingly, the NTSB recommends that NHTSA require the installation of BTSI systems or equivalent in newly manufactured heavy vehicles with automatic transmissions and other transmissions susceptible to unintended acceleration associated with pedal misapplication when starting from a parked position.

Although the widespread use of BTSI devices would reduce instances of pedal misapplication in initially stationary vehicles, these devices are ineffective in preventing accidents in vehicles that are already moving. In two of the five accidents discussed in this report (Liberty and Nanuet), the vehicles were in motion when the pedal misapplication occurred. In the most severe light vehicle pedal misapplication accident investigated by the NTSB (Santa Monica, California),[47] the automobile involved was also in motion. Research indicates that a significant number of pedal misapplications occur in vehicles that are in motion.[48]

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[45] H.R. 1216.

[46] Both light and heavy vehicles found to be susceptible to pedal misapplication when starting from a parked position are typically equipped with automatic transmissions.

[47] NTSB/HAR-04/04.

[48] R. Schmidt, D. Young, T. Ayres, and J. Wong, "Pedal Misapplications: Their Frequency and Variety Revealed Through Police Accident Reports," *Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting* (1997), pp. 1023–1027.

Pedal Design Investigation

Interlock technologies are effective for mitigating accidents caused by initially stationary vehicles but are ineffective in preventing accidents involving vehicles that are already moving. It is, therefore, essential to identify additional measures to prevent pedal misapplication or to mitigate its effects.

The Falls Township accident occurred while the driver was performing his typical daily route—but using a bus that was significantly different from the one to which he was normally assigned. The driver's usual bus incorporated a bulkhead-mounted accelerator pedal (see figure 4) that operated along a different arc of travel than the floor-mounted accelerator found on the accident bus. Moreover, each bus was equipped with a floor-mounted brake pedal that functioned along an arc of travel that was comparable to the accelerator on the accident bus. (See figure 5.)

Figure 4. Pedal configuration of Falls Township driver's usual bus.

Figure 5. Pedal configuration of exemplar Falls Township accident bus.

In 1994, another driver was involved in a collision while operating the Falls Township accident bus, only weeks after it had been placed in service. An investigation by the school district, with input from Thomas Built, concluded that this earlier accident was the result of pedal misapplication. Of particular interest, both drivers of the accident bus (in 2007 and in 1994) had previously operated buses manufactured by International Corporation. Accordingly, it appears that drivers transitioning from one bus to another—especially from a bus with a different pedal configuration—may be more prone to pedal application error.

When a driver firmly establishes a pattern of performance—that is, a habit—it is typically more difficult to learn a new, similar pattern of performance. People have a tendency to resort to habitual, over-learned behaviors, particularly during times of stress.[49] When people resort to doing things as they first learned them, and the circumstances call for a response that is slightly different, the result is a response that is inappropriate for the current circumstances—or, in other words, an error.

When the two Falls Township drivers operated the controls on the Thomas Built bus, where both pedals were mounted on the floor, they each lost the ability to distinguish the pedals based on the characteristic feedback inherent in their regular buses. Coupled with the limited spatial separation of the brake and the accelerator pedal in the replacement vehicles, the

[49] (a) L. Curry, "Habit as the Source of Inappropriate Response," *Ergonomics*, vol 18, no. 4 (1975), pp. 435–442; as cited in Schmidt (1989). (b) C. Gielen, R. Schmidt, and P. van den Heuvel, "On the Nature of Intersensory Facilitation of Reaction Time," *Perception and Psychophysics*, vol. 34, no. 2 (1983), pp. 161–168; as cited in Schmidt (1989).

propensity for misapplication was significant. To the extent that the drivers were dependent on kinesthetic or proprioceptive[50] feedback to recognize and correct errors of pedal application, prior learning interfered with their transition to the new pedal configuration, which did not offer the dissimilarity of pedals found in their regular bus.

The same condition applies to differences in the spatial location or orientation of the pedals—drivers anticipate the location of foot pedals (which they typically cannot see) based on prior experience. When the spatial location of pedals differs among vehicles, the driver may attempt to depress a pedal in the location where she expects it to be, rather than where it actually is. The result may be unintended actuation of the accelerator pedal (when the intention was to depress the brake) or simultaneous activation of the brake and accelerator pedals (because of their proximity).

As in the Falls Township accident, the Nanuet bus driver was driving a substitute vehicle—a 1995 Bluebird bus—because her 2004 International conventional-style school bus was being repaired. The pedals on the two buses are similar; however, the accelerator on the International bus is set further back than the brake pedal relative to the driver, while the two pedals are on the same plane in the accident Bluebird bus. (See figures 6 and 7.) Further, on the Nanuet driver's usual bus, a console is located immediately to the right of the accelerator; on the accident bus, there are no objects next to the accelerator—just empty space. As in the Falls Township accident, the Nanuet driver's learned pedal response from her usual bus likely interfered with her attempted braking response on the day of the accident. In addition, though the movement of the accelerator in the Nanuet accident bus is similar to the brake movement in the driver's usual bus, it is not the same as the accelerator movement in her usual bus—thereby reinforcing her belief that her foot was on the brake pedal.

[50] Proprioceptive refers to a sensory receptor—chiefly in muscles, tendons, and joints—that responds to internal stimuli.

Figure 6. Pedal configuration of Nanuet accident bus (Bluebird), with accelerator and brake pedals on same plane.

Figure 7. Pedal configuration of Nanuet driver's usual bus, showing accelerator set farther back than brake pedal and accelerator mounting below accelerator pedal.

Although the Liberty accident vehicle was the driver's usual bus, the accelerator pedal and the brake pedal were nearly identical. Figure 8 shows the pedal layout for the Liberty accident bus. In addition to having similar size, the two pedals had the same arc of travel and were both mounted to the vehicle at the bottom of the pedal.

Figure 8. Pedal configuration of Liberty accident bus.

The NTSB concludes that the Falls Township and Nanuet accidents demonstrate that unfamiliarity with the pedal configuration of an alternate bus may lead to error and pedal misapplication. Therefore, the NTSB recommends that the National Association of State Directors of Pupil Transportation Services and the National Association for Pupil Transportation advise their members—through their newsletters, websites, and conferences—of the risk of pedal misapplication and the need to educate school bus drivers about such incidents, and the need to develop and implement plans to ensure that school bus drivers undergo annual refamiliarization training on all bus types that they might drive.

The school transportation environment is the sole focus of the National Association of State Directors of Pupil Transportation Services, which was established in 1968 to provide leadership and assistance to the nation's school transportation industry. The association works closely with representatives from all 50 states, national organizations, and federal agencies to ensure safe, secure, healthy, and efficient transportation for school children.

The National Association for Pupil Transportation was established in 1974 to support professionals who provide pupil transportation services. Association members from the public sector, the private sector, vehicle manufacturing, after-market product manufacturing, and service providers all benefit from focused education, government relations, and research programs.

Pedal Design Research

Due in large part to the widely publicized incidents involving sudden automotive acceleration in the 1980s, NHTSA undertook a significant effort to identify pedal characteristics that might be associated with driver performance problems and to develop recommended pedal configurations.[51] After experimentally comparing an "expected" configuration to two alternate configurations in a passenger car, the researchers found no statistically significant differences in the number of errors among them. They did, however, classify the errors for all designs as "high" and concluded that a standardized configuration would provide a benefit by reducing pedal errors. NHTSA identified the need for additional information on driver-preferred pedal location, the unknown effect of other in-vehicle cues, the sample population used in the study, and the exact benefits to be realized through standardization. As the BTSI device was incorporated into later automobile models and the instances of sudden acceleration decreased, NHTSA concluded that the incorporation of this technology would prevent pedal misapplication and abandoned its efforts toward standardizing pedals. However, countermeasures other than BTSI devices need to be explored because pedal misapplication can occur when a vehicle is already in motion.

Many researchers have attempted to quantify the relationship between pedal misapplication and pedal design—with some concluding that design plays a role in pedal misapplication[52] and others maintaining that design has no significant effect.[53] Some researchers[54] have sidestepped traditional configurations and suggested markedly redesigned pedals to reduce the incidence of pedal misapplication while also decreasing brake reaction time. These researchers independently evaluated a design that combines the accelerator and brake in a single pedal, which pivots fore–aft about a central fulcrum. The driver accelerates by pressing fore with the toes and brakes by pressing aft with the heel. Study participants learned the configuration rapidly, experienced few to no errors, and indicated that they preferred the novel design to current vehicle pedal designs. At least one manufacturer (Volvo) has demonstrated the

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[51] R. Brackett, V. Pezoldt, M. Sherrod, and L. Roush, *Human Factors Analysis of Automotive Foot Pedals*, DOT HS 807 512 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1989).

[52] (a) J. Pollard and E. Sussman, *An Examination of Sudden Acceleration* (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1989). (b) Schmidt (1989). (c) R. Schmidt, "Unintended Acceleration: Human Performance Considerations," eds. B. Peacock and W. Karwowski, *Automotive Ergonomics* (London: Taylor & Francis, 1993), pp. 431–451.

[53] (a) M. Vernoy and J. Tomerlin, "Pedal Error and Misperceived Centerline in Eight Different Automobiles," *Human Factors*, vol. 31, no. 4 (1989), pp. 369–375. (b) Rogers and Wierwille (1988). (c) D. Trachtman, R. Schmidt, and D. Young, "The Role of Pedal Configuration in Unintended-Acceleration and Pedal-Error Accidents," *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting* (2005), pp. 1984–1988.

[54] (a) S. Konz, N. Wadhera, S. Sathaye, and S. Chawla, "Human Factors Considerations for a Combined Brake-Accelerator Pedal, *Ergonomics*, vol. 14, no. 2 (1971), pp. 279–292. (b) G. Poock, A. West, T. Toben, and J. Sullivan, "A Combined Accelerator-Brake Pedal," *Ergonomics*, vol. 16, no. 6 (1973), pp. 845–848. (c) S. Glass and C. Suggs, "Optimization of Vehicle Accelerator-Brake Pedal Foot Travel Time," *Applied Ergonomics*, vol. 8, no. 4 (1977), pp. 215–218. (d) R. Nilsson, "Evaluation of a Combined Brake-Accelerator Pedal," *Accident Analysis and Prevention*, vol. 34, no. 2 (2002), pp. 175–183.

engineering feasibility of the design and has implemented it on several prototype vehicles in Sweden.[55]

However, research has failed to yield a consensus on the relationship between pedal design and pedal misapplication. Given the variability in results of experiments on pedal design, the NTSB concludes that there is no consensus on the role of pedal design in pedal misapplication and unintended acceleration.

Although moving from one vehicle to another with a different pedal design may play a role in some instances of pedal misapplication, the research on the effect of such transfer from a usual vehicle to a different vehicle—as was the circumstance in both the Falls Township and Nanuet accidents—is inconclusive. Exacerbating the issue is the fact that very little of this research has been performed in heavy vehicles. One effort, published by the Transportation Research Board in 1997, looked at ergonomics and operator preference for bus operator work stations, but it did not consider pedal error or reaction time.[56] Therefore, the NTSB recommends that NHTSA analyze pedal configurations in heavy vehicles, including innovative designs, to determine the effect of pedal design on the driving task, examining—among other things—pedal error, reaction time, driver acceptance, and driver adaptation. Once the analysis of pedal configurations is complete, the NTSB recommends that NHTSA publish pedal design guidelines for designers and manufacturers.

Positive Separation

Although both BTSIs for heavy vehicles and pedal redesign have the potential to improve safety by reducing pedal misapplications, these solutions would likely apply only to newly manufactured vehicles—not vehicles currently on the road. Also, given the time required to conduct research, propose rulemaking, and implement a final rule, either remedy would require years to come to fruition. Therefore, it is necessary to examine ways to mitigate the effects of pedal misapplication in the near term, especially in areas where large numbers of people form queues to board buses.

Although positive separation—for example, bollards[57] or other physical barriers—is not a solution to the problem of unintended acceleration, it can mitigate pedestrian injuries that may result from pedal misapplication. Positive separation is not a new idea. As a result of the NTSB

[55] D. Graham-Rowe, "Combined Accelerator and Brake Pedal Could Save Lives," *New Scientist* (January 10, 2002). See <http://www.newscientist.com/article/dn1770-combined-accelerator-and-brake-pedal-could-save-lives.html> (accessed August 20, 2009).

[56] H. You, B. Osterling, J. Bucciaglia, B. Lowe, B. Gilmore, and A. Freivalds, *Bus Operator Workstation Evaluation and Design Guidelines: Summary*, TCRP Report 25 (Washington, DC: National Academy Press, 1997).

[57] A bollard is a post, pipe, or tube designed and positioned in series to prevent vehicular traffic from entering a particular area; bollards may be permanent or removable.

investigation into the Normandy, Missouri, accident[58]—also the result of pedal misapplication—the following recommendation was made to the Federal Highway Administration (FHWA):

H-98-1

> Ensure, in cooperation with the Federal Transit Administration, the American Association of State Highway and Transportation Officials, the American Public Transit Association, and the Community Transportation Association of America, that future transit facility designs incorporating "saw-tooth" bus parking bays, or other types of designs that direct errant vehicular traffic toward pedestrian-occupied areas, include provisions for positive separation between the roadway and pedestrian areas sufficient to stop a bus operating under normal parking area speed conditions from progressing into the pedestrian area.

Safety Recommendation H-98-1 was classified "Closed—Acceptable Alternate Action" on June 21, 2005, as a result of the FHWA's efforts to encourage the American Association of State Highway and Transportation Officials (AASHTO) to revise its publications. The NTSB made similar recommendations to the Federal Transit Administration (FTA), AASHTO, the American Public Transit Association (APTA), and the Community Transportation Association of America (CTAA), respectively:

- Safety Recommendation H-98-2, to the FTA, classified "Closed—Acceptable Action" on October 21, 1998, as a result of the FTA forwarding the text of the recommendation to its regional offices and instructing them to bring the issue to the attention of grantees.
- Safety Recommendation H-98-3, to AASHTO, classified "Closed—Unacceptable Action" on June 21, 2005, as a result of the NTSB receiving no response to the recommendation in 7 years.
- Safety Recommendation H-98-4, to APTA, classified "Closed—Acceptable Action" on January 23, 2002, as a result of APTA adopting a position that positive separation is needed between the roadway and pedestrians.
- Safety Recommendation H-98-6, to the CTAA, currently classified "Open—Await Response." In its latest correspondence with the CTAA, dated March 10, 2008, the NTSB noted that it had not yet received a response on this recommendation and advised the association that it would consider closing the recommendation in an unacceptable status.

[58] NTSB/HAR-98/01/SUM. In this accident, a transit bus collided with seven pedestrians in a "park and ride" facility. The bus was being operated by a 31-year-old driver trainee, who had just completed a routine stop at the station. After allowing the passengers to debark, the driver began to move the bus forward to provide clearance for another bus to pass. Reportedly unable to stop the bus, the driver allowed it to surmount the curb and continue onto the station platform. The NTSB determined that the probable cause of this accident was the driver's misapplication of the accelerator, resulting in the vehicle's override of the curb and travel onto the occupied pedestrian platform. Two safety issues were identified: the insufficiency of pedestrian protection provided by the saw-tooth parking bay design and the need for positive separation between the roadway and pedestrian areas of parking bay facilities.

Although there has been some progress on the above recommendations, the NTSB finds it disappointing that, in the 12 years since the Normandy, Missouri, accident, there is still no *requirement* for positive separation of pedestrians and traffic in transit facilities. However, some jurisdictions have taken voluntary action. The city of New Orleans, Louisiana, for example, has employed positive separation since the early 1980s to keep errant vehicles out of the pedestrian mall on Bourbon Street. Although the city does not keep records of the effectiveness of these measures, damage to the bollards and the lack of reports of vehicles entering the pedestrian mall indicate that the bollards have served their intended purpose. Following the Falls Township accident discussed above, the Pennsbury School District installed positive separation at Pennsbury High School, seeking to protect students and other pedestrians from errant vehicles.

The school environment presents a unique risk with respect to unintended acceleration. A typical loading or unloading operation involves multiple vehicles and many children. Often, the children line up, wait, or congregate near the buses, as was the case in the Falls Township and Newtown accidents. Every bus at the loading area can introduce an opportunity for pedal misapplication, and the large number of children represents a potential increase in the severity of the outcome should pedal misapplication and unintended acceleration occur. Therefore, the NTSB concludes that the nature of the bus loading and unloading activities at schools creates a situation where an errant vehicle, such as one experiencing an unintended acceleration, could easily strike pedestrians.

The NTSB's 1998 recommendations, previously listed, do not address the potential hazard posed during bus loading and unloading at schools, as demonstrated by the Falls Township accident. Therefore, the NTSB recommends that the National Association of State Directors of Pupil Transportation Services and the National Association for Pupil Transportation advise their members—through their newsletters, websites, and conferences—of the risk of unintended acceleration during loading and unloading activities, as exemplified by the Falls Township, Pennsylvania, accident on January 12, 2007; and suggest possible mitigation strategies, such as installing bollards or starting buses only after loading is complete. Furthermore, the NTSB is reclassifying Safety Recommendation H-98-6 to "Closed—Unacceptable Action/No Response Received" because of receiving no response from the CTAA.

Highway Vehicle Event Data Recorders

EDRs are devices or functions in a vehicle that record dynamic, time-series data (such as vehicle speed vs. time) in the period just prior to or during a crash event (for example, delta-V vs. time).[59] The data are intended for later retrieval and can assist accident investigators.

In August 2006, NHTSA published a final rule that standardized the information EDRs collect to facilitate data retrieval and also addressed the survivability requirements for EDRs,

[59] Event Data Recorders, 49 *United States Code* (U.S.C.) 563.5.

basing those criteria on current *Federal Motor Vehicle Safety Standards* (FMVSS).[60] The rule, FMVSS 563, was amended on January 14, 2008, to allow more time for manufacturers to comply.

However, it is important to note that the current data and performance standards established by FMVSS 563 do not require vehicles to actually be equipped with an EDR, but rather establish data and performance standards for EDRs that may be voluntarily installed by the manufacturer. Although this rule represents an important step in the process of developing EDRs for light vehicles, it currently excludes vehicles with a GVWR over 8,500 pounds and, therefore, does not apply to buses, motorcoaches, or other heavy vehicles.

There has also been some activity in developing EDR standards for heavy vehicles. In 1999, as a result of its special investigation of bus crashworthiness,[61] the NTSB made two EDR-related recommendations to NHTSA:

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

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

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

penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances.

In October 2000, NHTSA organized the truck and bus EDR working group to focus on data elements, survivability, and event definitions related to trucks, school buses, and motorcoaches. Findings were published in May 2002.[62]

In 2004, the National Cooperative Highway Research Program (NCHRP) examined current U.S. and international methods and practices for the collection, retrieval, archiving, and analysis of EDR data for roadside and vehicle safety.[63]

In 2004, both IEEE[64] and the Society of Automotive Engineers (SAE) published voluntary standards and recommended practices regarding highway vehicle EDRs.[65] IEEE completed project 1616 by publishing the first established standards for motor vehicle EDRs—standards that encompassed all highway vehicles on both light and heavy vehicle platforms. The SAE published a voluntary industry recommended practice (J1698) for displaying and presenting EDR data. This recommended practice was an effort to establish a standardized format for displaying and presenting crash-related data that had been recorded or stored by the electronic components currently installed in many light-duty vehicles. It applies specifically to the postevent format of downloaded data and does not direct how the data should be collected or which vehicle systems should be monitored. Further, SAE J1698 applies to data from frontal impacts only. SAE has not proceeded with plans to continue the standardization of EDR data by developing recommended practices for additional collision types, including multiple impacts, side impacts, and rollovers.

An additional SAE working group is reportedly near completion of a recommended practice for heavy vehicle EDRs. SAE J2728 addresses the following for medium- and heavy-duty vehicles: event triggers, data elements, event record duration, time stamping, recording rate, file format, performance requirements, electrical and environmental performance, survivability, power reserves, security, data volatility, access, interfaces, extraction procedures, and alternative extraction methods.

Additional industry initiatives include the American Trucking Associations publication of a recommended practice (RP1214) to define the collection of event-related data on board

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

[63] H. Gabler, D. Gabauer, H. Newell, and M. O'Neill, *Use of Event Data Recorder Technology for Highway Crash Data Analysis*, NCHRP Project 17-24 (Washington, DC: Transportation Research Board, 2004).

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

[65] (a) *IEEE Standard* for *Motor Vehicle Event Data Recorders*, IEEE Standard 1616-2004 (Los Alamitos, California: IEEE, February 2005). (b) Society of Automotive Engineers International, *Vehicle Event Data Recorder Interface—Output Data Format*, SAE Recommended Practice J1698-1 (December 2003).

commercial vehicles. This recommended practice, intended for mechanics, outlines data elements, storage methodology, and retrieval approach for event data.

The Commercial Vehicle Safety Technology Diagnostics and Performance Enhancement Program of the Federal Motor Carrier Safety Administration (FMCSA), also known as the CV Sensor Study, has worked to define advanced on-board diagnostic and improved safety-related products for trucks and tractor-trailers. The program has developed functional EDR requirements for the analysis of accident data from the FMCSA's Large Truck Crash Causation Study for both complete accident reconstruction and crash analyses. The CV Sensor Study has also developed requirements for EDR components, hardware, software, sensors, and databases, and has completed a cost-effectiveness analysis.[66] During the 2007 SAE symposium on highway EDRs,[67] industry representatives discussed the status of standards work; current system operating experience; and evidence that many operators currently use vehicle data recorders to improve operational control, to support insurance rates and claims, and to respond to litigation.

The pedal misapplication incidents discussed in this report exemplify heavy vehicle accidents in which EDRs would have provided essential data. Although research and human factors principles provide a compelling explanation for unintended acceleration incidents in which no mechanical cause is found, some people remain skeptical that pedal misapplication is the cause of such accidents. If these vehicles were equipped with EDRs, the question of the drivers' actions during specific events could be documented, and investigators would have a physical record of specific actions and control inputs. Had any of the vehicles involved in these accidents been equipped with an EDR, a significantly higher level of science could have been applied to understanding the accident. The NTSB concludes that EDRs would provide essential and specific information regarding the causes and mechanisms of pedal misapplication and unintended acceleration in heavy as well as light vehicles.

Recognizing the work of NHTSA in formally requesting comments on bus EDRs and participating in working groups developing standards for EDRs, the NTSB classified both Safety Recommendations H-99-53 and -54 as "Open—Acceptable Response" on April 15, 2004. However, the NTSB reiterated these two recommendations on August 18, 2008, in a report on the motorcoach accident in Atlanta, Georgia, involving 33 members of the Bluffton University baseball team.[68] The NTSB's investigation of the crash dynamics and injury mechanisms was limited because of the lack of an EDR on the motorcoach. Despite the reiteration of Safety Recommendations H-99-53 and -54, NHTSA has not yet implemented a requirement for the use of EDRs on buses. Accordingly, the NTSB is reclassifying Safety Recommendations H-99-53 and -54 to "Open—Unacceptable Response" and reiterating them again in this report.

[66] See FHWA IVI Program 134, "Development of Requirements and Functional Specifications for Event Data Recorders," <http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14146.htm> (accessed April 3, 2008).

[67] Society of Automotive Engineers International, *Highway Vehicle Event Data Recorder Symposium, September 5-6, 2007, Ashburn, Virginia* (2007).

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

Conclusions

Findings

1. Neither the licensing nor the training of the Liberty, Missouri, driver contributed to the accident, and neither drugs nor alcohol impaired the driver's performance.

2. The Liberty, Missouri, accident cannot be attributed to a mechanical failure of the school bus.

3. The circumstances of the Liberty, Missouri, accident are consistent with driver pedal misapplication.

4. Neither the licensing nor the training of the Falls Township, Pennsylvania, driver was a factor in the accident, and neither drugs nor alcohol impaired the driver's performance.

5. The Falls Township, Pennsylvania, accident cannot be attributed to a mechanical failure of the school bus.

6. The circumstances of the Falls Township, Pennsylvania, accident are consistent with driver pedal misapplication.

7. The Falls Township, Pennsylvania, driver's unfamiliarity with the school bus contributed to the occurrence of pedal misapplication.

8. Pedal misapplication was the initiating event in the accidents in Asbury Park, New Jersey; Nanuet, New York; and Newtown, Pennsylvania.

9. A brake transmission shift interlock device would have prevented the accidents in Falls Township, Pennsylvania; Asbury Park, New Jersey; and Newtown, Pennsylvania.

10. Given the demonstrated benefits of brake transmission shift interlock systems in passenger cars and the fact that the mechanisms that cause pedal misapplications are dependent on the human driver and are, therefore, similar in both light and heavy vehicles, requiring interlock devices in heavy vehicles susceptible to pedal misapplication would provide a safety benefit by reducing such instances and unintended acceleration.

11. The Falls Township, Pennsylvania, and Nanuet, New York, accidents demonstrate that unfamiliarity with the pedal configuration of an alternate bus may lead to error and pedal misapplication.

12. Given the variability in results of experiments on pedal design, there is no consensus on the role of pedal design in pedal misapplication and unintended acceleration.

13. The nature of the bus loading and unloading activities at schools creates a situation where an errant vehicle, such as one experiencing an unintended acceleration, could easily strike pedestrians.

14. Event data recorders would provide essential and specific information regarding the causes and mechanisms of pedal misapplication and unintended acceleration in heavy as well as light vehicles.

Probable Cause

Liberty, Missouri, Accident

The National Transportation Safety Board determines that the probable cause of the Liberty, Missouri, accident on May 9, 2005, was a pedal misapplication by the school bus driver.

Falls Township, Pennsylvania, Accident

The National Transportation Safety Board determines that the probable cause of the January 12, 2007, accident in Falls Township, Pennsylvania, was a pedal misapplication by the driver. Contributing to the occurrence of pedal misapplication was the driver's unfamiliarity with the school bus.

Recommendations

New Recommendations

As a result of the investigation of the five accidents covered in this special investigation report, the National Transportation Safety Board makes the following safety recommendations:

To the National Highway Traffic Safety Administration:

Require the installation of brake transmission shift interlock systems or equivalent in newly manufactured heavy vehicles with automatic transmissions and other transmissions susceptible to unintended acceleration associated with pedal misapplication when starting from a parked position. (H-09-11)

Analyze pedal configurations in heavy vehicles, including innovative designs, to determine the effect of pedal design on the driving task, examining—among other things—pedal error, reaction time, driver acceptance, and driver adaptation. (H-09-12)

Once the analysis of pedal configurations requested in Safety Recommendation H-09-12 is complete, publish pedal design guidelines for designers and manufacturers. (H-09-13)

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

Advise your members—through your newsletters, websites, and conferences—of the following safety issues: (1) the risk of pedal misapplication and the need to educate school bus drivers about such incidents, and the need to develop and implement plans to ensure that school bus drivers undergo annual refamiliarization training on all bus types that they might drive; and (2) the risk of unintended acceleration during loading and unloading activities, as exemplified by the Falls Township, Pennsylvania, accident on January 12, 2007; and suggest possible mitigation strategies, such as installing bollards or starting buses only after loading is complete. (H-09-14)

Previously Issued Recommendations Reiterated and Reclassified in This Report

The National Transportation Safety Board reiterates and reclassifies Safety Recommendations H-99-53 and -54. These two recommendations, previously classified "Open—Acceptable Response," are reclassified "Open—Unacceptable Response" in the "Highway Vehicle Event Data Recorders" section of this report.

To the National Highway Traffic Safety Administration:

> Require that all school buses and motorcoaches manufactured after January 1, 2003, be equipped with on-board recording systems that record vehicle parameters, including, at minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left/right), brake light status (on/off), head/tail light status (on/off), passenger door status (open/closed), emergency door status (open/closed), hazard light status (on/off), brake system status (normal/warning), and flashing red light status (on/off) (school buses only). For those buses so equipped, the following should also be recorded: status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy. The on-board recording system should record data at a sampling rate that is sufficient to define vehicle dynamics and should be capable of preserving data in the event of a vehicle crash or an electrical power loss. In addition, the on-board recording system should be mounted to the bus body, not the chassis, to ensure that the data necessary for defining bus body motion are recorded. (H-99-53)

> Develop and implement, in cooperation with other government agencies and industry, standards for on-board recording of bus crash data that address, at a minimum, parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid submersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances. (H-99-54)

Previously Issued Recommendation Reclassified in This Report

The National Transportation Safety Board reclassifies Safety Recommendation H-98-6 from its current classification of "Open—Await Response" to "Closed—Unacceptable Action/No Response Received" in the "Positive Separation" section of this report.

To the Community Transportation Association of America:

> Ensure, in cooperation with the Federal Highway Administration, the Federal Transit Administration, the American Association of State Highway and Transportation Officials, and the American Public Transit Association, that future transit facility designs incorporating "saw-tooth" bus parking bays, or other types of designs that direct errant vehicular traffic toward pedestrian-occupied areas, include provisions for positive separation between the roadway and pedestrian areas sufficient to stop a bus operating under normal parking area speed conditions from progressing into the pedestrian area. (H-98-6)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

DEBORAH A.P. HERSMAN
Chairman

ROBERT L. SUMWALT
Member

CHRISTOPHER A. HART
Vice Chairman

Adopted: September 1, 2009

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Appendix A: Investigations

The National Transportation Safety Board (NTSB) was notified of the Liberty, Missouri, accident on May 9, 2005. Investigators were dispatched from the Washington, D.C.; Atlanta, Georgia; Gardena, California; Arlington, Texas; Parsippany, New Jersey; and Denver, Colorado, offices. Groups were established to investigate highway, human performance, vehicle, motor carrier, event data recorder, and survival factors. The Liberty Police Department, Liberty Public Schools, Missouri State Highway Patrol, Missouri Department of Transportation, Thomas Built Buses, Inc., Bendix Commercial Vehicle Systems LLC, Williams Controls, and Cummins Engine Company participated in the investigation.

The NTSB was notified of the accident in Falls Township, Pennsylvania, on January 12, 2007. Investigators were dispatched from the Washington, D.C., and Parsippany, New Jersey, offices. Groups were established to investigate motor carrier, human performance, and vehicle factors. The Falls Township Police Department, Thomas Built Buses, Inc., Bendix Commercial Vehicle Systems LLC, and Williams Controls participated in the investigation.

The Asbury Park, New Jersey; Nanuet, New York; and Newtown, Pennsylvania, accidents were investigated by NTSB staff from the Washington, D.C., office.

Table A-1 summarizes accident data and applicable countermeasures for the subject accidents discussed in this report. In the case of each of these five investigations, no Board member was on scene. No public hearings were held; no depositions were taken.

Table A-1. Summary of pedal misapplication accident data.

Location	Date	Vehicle	Age of Driver	Fatalities	Injuries	Countermeasures[a]
Liberty, Missouri	05/09/2005	School bus	45	2	49	Pedal design EDRs
Falls Township, Pennsylvania	01/12/2007	School bus	54	0	22	Pedal design BTSI Positive separation EDRs
Asbury Park, New Jersey	11/22/2006	Fire truck	33	0	0	Pedal design BTSI EDR
Nanuet, New York	01/12/2007	School bus	35	0	1	Pedal design EDR
Newtown, Pennsylvania	02/11/2008	School bus	61	0	0	Pedal design BTSI Positive separation EDR

[a]EDR (event data recorder), BTSI (brake transmission shift interlock).

Appendix B: Liberty School Bus Mechanical Inspection

Brake System

The Liberty, Missouri, school bus was equipped with an airbrake system consisting of a single compressor, type 24L chambers on the front brakes, and type 30/30[1] chambers on the rear brakes. All four brakes were equipped with automatic slack adjusters.[2] The four-channel antilock braking system (ABS) consisted of an electronic control unit (ECU), sensors at each wheel position, and a modulator value for each wheel. The air brake system was not equipped, nor was it required to be equipped, with a brake transmission shift interlock (BTSI), which would have required application of the brake pedal to shift the transmission into drive. Likewise, the vehicle was not equipped, nor was it required to be equipped, with a control valve necessitating that the brake pedal be depressed when releasing the parking brake. The initial inspection by the Missouri State Highway Patrol uncovered three leaks in the air system, which were determined to have been caused by the accident.

The three leaks were repaired at the highway maintenance facility, and air was supplied to the system using an auxiliary compressor. An air regulator set at 85 psi was used to control the supply of air; no audible leaks were present. Pushrod measurements were taken by depressing the brake pedal, activating the system. Table B-1 shows pushrod measurements for each of the four brakes.

Table B-1. Pushrod measurements for Liberty school bus brakes.

Axle[a]	Chamber Size	Slack Arm Length (inches)	Measured Stroke (inches)	Adjustment Limit (inches)
1L	24L	5 1/2	3/4	2
1R	24L	5 1/2	7/8	2
2L	30/30	6	1[b]	2
2R	30/30	6	1 5/8	2

[a]Axle 1L is the first axle, left side; axle 1R is the first axle, right side, etc.

[b]The left rear tire, rim, drum, and brake shoe were all damaged, with the shoe table (shoe base) being bent. Therefore, the accuracy of this pushrod measurement is uncertain; the true pushrod stroke is most likely at least slightly longer than the measured stroke.

[1] This chamber consists of a type 30 service chamber and a type 30 emergency/parking brake chamber.

[2] Automatic slack adjusters are also known as automatic brake adjusters.

During an air bleed-down test performed by applying the brake pedal, the low air warning light and buzzer activated at 70 psi, and the parking brakes applied fully at 40 psi. All four brake drums were removed and found to be generally smooth and without grooves. The brake shoes were examined and were found to be unremarkable, with thickness ranging from 9/32–5/8 inch.

Pneumatic Brake Control System

Examination of the pneumatic brake control system included checking for current faults in the ECU, continuity testing of the vehicle's ABS-related wires, resistance testing of sensors and modulator valves, test firing of modulator valves, physical examination of gaps between the sensors and tone rings, and testing of brake timing and balance. Additionally, the ABS ECU was removed from the accident bus and installed in an identically equipped exemplar bus and road tested. A full range of brake applications were made, from light to forceful, and the brake system functioned normally. No abnormalities were found in the examination and testing of the ABS system.

Brake Pedal and Valve

The brake pedal and valve were removed from the accident bus for examination. The brake valve was tested for function and leaks using a test stand. Although slight air leakage was observed, the valve was found to be within the manufacturer's engineering standards for a new valve.

Accelerator Pedal

When a jump wire was used to bypass crash-related damage, the vehicle's engine would accelerate and decelerate normally when the pedal was depressed and released. The pedal was observed to move smoothly. Continuity and resistance testing resulted in values consistent with a properly operating accelerator pedal.

Steering

The school bus was equipped with a hydraulic power steering unit. All steering linkage was found to be intact, with no play detected. The steering wheel had a minimal amount of free play; rotation of the steering wheel resulted in corresponding tire movement.

Brake Lights

The vehicle's rear brake lights were tested by depressing the brake pedal with the power on. All four rear lights illuminated when either the primary or secondary switch was used.

Appendix C: Falls Township School Bus Mechanical Inspection

Brake System

The Falls Township, Pennsylvania, school bus was equipped with an airbrake system consisting of a single compressor, type 20 chambers on the front brakes, and type 30/30 chambers on the rear brakes. All four brakes were equipped with automatic slack adjusters. When air was supplied to the brake system's primary air tank, an air leak was detected from the area of the dashboard. The leak subsided when two pneumatic lines running behind the dash, determined to have been damaged in the crash, were pinched off (later capped).

Air was allowed to build up in the primary tank to approximately 90 psi, and the parking brake was released. The pushrod position was marked in the released position; the brake pedal was fully applied, and the pushrod position was re-marked. Table C-1 shows pushrod measurements for each of the four brakes.

Table C-1. Pushrod measurements for Falls Township school bus brakes.

Axle[a]	Chamber Size	Slack Arm Length (inches)	Measured Stroke (inches)	Adjustment Limit (inches)
1L	20	5 1/2	1 3/4	1 3/4
1R	20	5 1/2	1 5/8	1 3/4
2L	30/30	5 1/2	2 1/8	2
2R	30/30	5 1/2	2 3/8	2

[a]Axle 1L is the first axle, left side; axle 1R is the first axle, right side, etc.

The air brake system was not equipped, nor was it required to be equipped, with a brake transmission shift interlock, which would have required the brake pedal to be applied to shift the transmission into drive. Likewise, the vehicle was not equipped, nor was it required to be equipped, with a control valve necessitating that the brake pedal be depressed when releasing the parking brake.

Accelerator Pedal

The Falls Township school bus was equipped with a completely air-operated accelerator pedal with no electrical connections. As a result of the accident, a portion of the dash had been pushed into the area of the foot pedals and was in contact with the right edge of the accelerator pedal, keeping it from returning to the idle position. When the obstruction was removed, the pedal returned to idle and operated normally thereafter. No anomalies were found in the two air lines connected to the accelerator pedal cylinder. Inspection of the throttle linkage revealed a modified external return spring configuration involving the use of additional wire.[1] Despite this configuration, when the throttle was moved, it returned without restriction, both with and without the external return spring attached. Nothing was noted that would interfere with movement of the throttle linkage.

Steering System

The steering system of the bus consisted of a steering column into a TRW Ross hydraulic power steering gearbox. Upon inspection, the gearbox was observed to be solidly attached to the pitman arm. The accident caused a tear in the grease seal at the attachment of the pitman arm to the drag link. The drag link remained attached to the upper steering arm on the left-front wheel, as did the steering linkage between the left- and right-front wheels. All joints appeared to be lubricated. No excessive free play was observed in the linkage. When the steering wheel was rotated, the front wheels turned without restriction.

Brake Lights

When the brake/tail light lenses were removed from the four brake/tail lights on the rear of the bus, the filaments were found to be coiled and continuous. The brake/tail light lenses were replaced, and the vehicle's brake pedal was depressed. All four rear brake lights illuminated.

Pedal Configuration

In the accident bus, the brake pedal was metal and oblong, with a maximum length of 11 inches and a maximum width of 3 inches. The left edge of the brake pedal was 1.25 inches from the steering column enclosure. The brake pedal was 1 inch off the floor at the proximal edge and 6.5 inches off the floor at the distal edge.

The accelerator pedal was metal and rectangular, with a maximum length of 11.375 inches and a maximum width of 2.75 inches. It was 1.75 inches off the floor at the proximal end and 8 inches off the floor at the distal end. The center of the accelerator pedal was roughly in line with the right edge of the driver's seat. The brake pedal and the accelerator pedal were parallel and 2 inches apart both proximally and distally.

[1] The external return spring is not essential to operation of the throttle system; an internal spring within the throttle assembly returns the throttle. The external return spring is a fail-safe for that internal spring.

On the driver’s usual bus, the brake pedal is a metal oblong with a maximum length of 10.625 inches and a maximum width of 3 inches. The height of the brake pedal from the floor is 0.875 inch at the proximal edge and 8.875 inches at the distal edge. The pedal is located approximately 0.635 inch from the steering column enclosure.

The accelerator pedal is roughly rectangular with an angled top. It is 6 inches long on the left edge and 6.125 inches long on the right edge, and 2 inches wide. It is 2.875 inches above the floor at the proximal edge and 6.25 inches above the floor at the distal edge. The right edge of the accelerator pedal is located 2.5 inches proximally and 2 inches distally from the right side of the foot well, roughly in line with the right edge of the driver’s seat. Interpedal spacing between the brake and accelerator pedal is 1.875 inches proximally and 2.375 inches distally.