National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: July 8, 2010

In reply refer to: H-10-1 through -7, and
H-99-43, -44, -53, and
H-09-23 and -24
(Reclassification)

The Honorable David L. Strickland
Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue, SE
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Washington, D.C. 20590

On Friday, January 30, 2009, about 4:06 p.m. mountain standard time, a 2007 Chevrolet/Starcraft 29-passenger medium-size bus, operated by DW Tour and Charter and occupied by the driver and 16 passengers, was traveling northbound in the right lane of U.S. Highway 93, a four-lane divided highway, near Dolan Springs, in Mohave County, Arizona.[1] The bus was on a return trip from Grand Canyon West to Las Vegas, Nevada, after a day-long tour. As the bus approached milepost 28 at a speed of 70 mph,[2] it moved to the left and out of its lane of travel. The driver steered sharply back to the right, crossing both northbound lanes and entering the right shoulder. The driver subsequently overcorrected to the left, causing the bus to yaw and cross both northbound lanes. The bus then entered the depressed earthen median and overturned 1.25 times before coming to rest on its right side across both southbound lanes. During the rollover sequence, 15 of the 17 occupants (including the driver) were fully or partially ejected. Seven passengers were killed, and nine passengers and the driver received injuries ranging from minor to serious. At the time of the accident, skies were clear, the temperature was 61° F, and the wind was blowing from the north–northeast at 8 mph.

The National Transportation Safety Board determined that the probable cause of the accident near Dolan Springs, Arizona, was the bus driver's inadvertent drift from the driving lane due to distraction caused by his manipulation of the driver's side door and subsequent abrupt steering maneuver, which led to losing directional control of the vehicle. Contributing to the severity of the accident was the lack of both occupant protection and advanced window glazing standards for medium-size buses.

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[1] *Bus Loss of Control and Rollover, Dolan Springs, Arizona, January 30, 2009,* Highway Accident Report NTSB/HAR-10/01 (Washington, DC: National Transportation Safety Board, 2010), which is available on the NTSB website at <http://www.ntsb.gov/publictn/2010/HAR1001.pdf>.

[2] This speed was based on readings from a global positioning system unit found in the accident vehicle. Skid tests performed on scene resulted in the determination of a vehicle speed of 70–72 mph.

Lane Departure Warning Systems

It has been estimated that 20 percent of all police-reported accidents involve vehicles running off the road, leading to 41 percent of all vehicle fatalities.[3] A majority of these accidents occur on straight roadways (76 percent) and in good weather conditions (73 percent). Lane departure warning systems (LDWS) are forward-looking video-based systems that warn the driver if the vehicle drifts from the lane. Most such systems are activated only when the vehicle is traveling over a certain speed (generally 35 mph) and when the driver initiates a lane departure without signaling the intent to do so.[4]

In a field operation test sponsored by the National Highway Traffic Safety Administration (NHTSA), an LDWS—when compared with baseline driving without this technology—was found to increase turn signal usage per mile driven by 9 percent, to decrease lane position deviation, and to cause drivers to more quickly return to their travel lane after being issued an imminent alert.[5] The effectiveness of LDWSs has varied along with such factors as the field testing environment, driving population, and test design; however, researchers predict that LDWSs could reduce heavy truck road departure crashes by 17–24 percent.[6] The Federal Motor Carrier Safety Administration (FMCSA) has already developed voluntary standards for LDWS functional, data, hardware and software, driver–vehicle interface, and maintenance and support requirements for vehicles above 10,000 pounds gross vehicle weight rating (GVWR).[7]

In its investigative report on a 2005 motorcoach collision with an overturned truck in Osseo, Wisconsin, the NTSB described LDWSs as a tool to warn drivers about unintended lane shifts regardless of whether they are impaired by fatigue, distraction, poor driving, or other conditions.[8] Furthermore, LDWSs can help prevent single-vehicle roadway departures, lane change/merge incidents, and head-on crashes. The NTSB concludes that, had the accident bus been equipped with an LDWS, the driver would have been alerted to the leftward drift of the bus, which might have provided an opportunity to take corrective action in a timely manner, thus avoiding the severe steering maneuver to the right that initiated the accident sequence. Because standards have already been established for vehicles above 10,000 pounds GVWR and several

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[3] D. Pomerleau and others, *Run-Off-Road Collision Avoidance Using IVHS Countermeasures*, DOT HS 809 170 (Washington, DC: National Highway Traffic Safety Administration, 1999).

[4] P. Rau, "Drowsy Driver Detection and Warning System for Commercial Vehicle Drivers: Field Operational Test Design, Data Analyses, and Progress," *Proceedings, 19th International Technical Conference on the Enhanced Safety of Vehicles*, DOT HS 809 825 (Washington, DC: National Highway Traffic Safety Administration, June 2005).

[5] D. LeBlanc and others, *Road Departure Crash Warning System Field Operational Test: Methodology and Results*, UMTRI 2006-9-1 (Ann Arbor, Michigan: University of Michigan Transportation Research Institute, June 2006).

[6] S. Johnson, *Human Factors Study of Driver Assistance Systems to Reduce Lane Departures and Side Collision Accidents* (Fayetteville, Arkansas: Mack–Blackwell National Rural Transportation Study Center, 2008).

[7] A. Houser and others, *Concept of Operations and Voluntary Operational Requirements for Lane Departure Warning Systems (LDWS) On-Board Commercial Motor Vehicles*, FMCSA-MCRR-05-005 (Washington, DC: Federal Motor Carrier Safety Administration, 2005).

[8] Truck-Tractor Semitrailer Rollover and Motorcoach Collision With Overturned Truck, Interstate Highway 94 Near Osseo, Wisconsin, October 16, 2005, Highway Accident Report NTSB/HAR-08/02 (Washington, DC: National Transportation Safety Board, 2008).

LDWS field tests have predicted steep reductions in accidents such as the one that killed seven passengers in Dolan Springs, the NTSB recommends that NHTSA require new commercial motor vehicles with a GVWR above 10,000 pounds to be equipped with LDWSs.

Regulatory Definition of Buses

Federal regulations do not provide a standard definition of a bus; and even among U.S. Department of Transportation (DOT) agencies, the term "bus" may refer to vastly different types of vehicles, from taxis to motorcoaches. The *Federal Motor Vehicle Safety Standards* (FMVSSs) do not differentiate among bus body types other than to distinguish between school bus and "not a school bus." Consequently, the bus body type classifications used by NHTSA for its accident databases and guidelines are not always consistent or well defined and do not have a regulatory basis.

An example of the vague and confusing nature of current bus definitions is illustrated by the term "motorcoach," which is used prominently in the DOT's recently published motorcoach safety action plan.[9] "Motorcoach" is not defined in Federal regulations, though it is commonly interpreted to mean a large bus characterized by an elevated passenger deck located over a baggage compartment. Although all 15 bus photographs in the action plan fit the common interpretation, the action plan itself does not define motorcoach. In the Fatality Analysis Reporting System (FARS), a motorcoach would generally be classified as an intercity/cross-country bus. Multistage vehicles such as the Dolan Springs accident bus would generally be categorized as "other" or "unknown" bus body types, along with trolley buses, amphibious buses ("ducks"), and a variety of other bus configurations. However, because the Dolan Springs accident bus was being used for intercity travel, it could also be classified, along with motorcoaches, in the intercity/cross-country bus category. In addition, several multistage medium-size buses are sold in the United States with the appearance and features of traditional motorcoaches, such as rear engines, lavatories, video systems, and baggage compartments over an elevated passenger deck,[10] and some are even marketed as small motorcoaches.

The ability to classify buses of different manufacture, weight, and range of passenger capacity under more than one FARS bus body attribute creates ambiguity in the data and weakens the meaning of each attribute. Consequently, the statistical analyses presented in the accident report on medium-size bus characteristics, usage, and fatal accident involvement do not rely solely on bus body type classifications to identify medium-size buses but instead use multiple FARS criteria, combined with make, model, and vehicle identification number.

The NTSB first examined the lack of standard bus definitions and classifications in its 1999 bus crashworthiness special investigation.[11] The NTSB expressed particular concern that

[9] *Motorcoach Safety Action Plan*, DOT HS 811 177 (Washington, DC: U.S. Department of Transportation, November 2009).

[10] Stallion Bus Industries and Ciao North America are two companies that build multistage medium-size buses for the U.S. market that have the appearance and features of traditional large motorcoaches.

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

FARS did not include a separate category for specialty buses (multistage vehicles) and van-based vehicles. As a result of its findings, the NTSB issued two recommendations to the DOT:

> H-99-43
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> In 1 year and in cooperation with the bus manufacturers, complete the development of standard definitions and classifications for each of the different bus body types, and include these definitions and classifications in the *Federal Motor Vehicle Safety Standards*.
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> H-99-44
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> Once the standard definitions and classifications for each of the different bus body types have been established in the *Federal Motor Vehicle Safety Standards*, in cooperation with the National Association of Governors' Highway Safety Representatives, amend the Model Minimum Uniform Crash Criteria's bus configuration coding to incorporate the FMVSS definitions and standards.

In April 2000, the NTSB added both Safety Recommendations H-99-43 and -44 to its Most Wanted List of Transportation Safety Improvements. In November 1999, the DOT had formed the "One DOT" task force to develop a plan of action for addressing the lack of a standard bus definition. The task force focused primarily on the classification of multistage vehicles and determined that because bus use varied considerably and often changed, the DOT should base its classification on basic descriptive information, such as length and seating configuration. The task force also determined that descriptive information could be encoded on the final stage manufacturer's certification label, in addition to the vehicle identification number. In 2005, NHTSA published a notice of proposed rulemaking (NPRM) to add encoded descriptive information on the final stage manufacturer's certification label for multistage vehicles, but the rulemaking was terminated in 2007 so that NHTSA could pursue a solution that would not unnecessarily burden bus manufacturers and would be more cost-effective for the states to implement. As an alternative measure, NHTSA worked with an expert panel, including NTSB representatives, to modify the Model Minimum Uniform Crash Criteria (MMUCC) guidelines to ensure that police reports include information that identifies vehicles manufactured in multiple stages. In 2006, the NTSB removed Safety Recommendations H-99-43 and -44 from the Most Wanted List, classifying them as "Open—Acceptable Alternate Response" and "Open—Acceptable Response," respectively.

Although NHTSA has made substantial progress in encouraging the states to base their police accident reports on the MMUCC guidelines, inconsistencies among the most basic regulatory definitions and descriptions for buses undermine the reliability and validity of the data collected. The 2008 version of the MMUCC distinguishes bus body types in a similar manner as FARS, with the only difference being the characterization of intercity/cross-country buses as motorcoaches. The MMUCC website provides users with more detailed descriptions of categories and attributes, along with illustrations of cars, buses, and trucks. The website and accompanying photographs are helpful for distinguishing among more traditional bus body configurations but do not clarify the body type distinctions between motorcoaches and some multistage medium-size buses. Finally, the MMUCC defines a bus as a motor vehicle with seating to transport 9 or more people (including the driver), which is consistent with FARS but inconsistent with the FMVSS definition of a bus as a vehicle that seats more than 10 people.

Regulatory definitions strongly influence the nature and scope of public policy decisions. Definitions provide the parameters from which classifications are based; and classifications determine the accident data to be gathered, how the data are analyzed, and how the results are interpreted. The interpretation of these results affects how research funding is allocated and, ultimately, what regulations are enacted. Therefore, the absence of uniform and unambiguous definitions can affect all aspects of regulatory decision-making—from the way issues are framed to the way solutions are implemented.

The DOT's motorcoach action plan is an ambitious document that provides the status of ongoing bus safety research and rulemaking, as well as a roadmap of future initiatives. Most of the activities described in the action plan are based on a strong body of research that spans passenger vehicle and truck safety as well as bus safety. The DOT has taken a systems approach to address motorcoach safety, evaluating the role of both the driver and the vehicle in crash and injury causation. However, because the DOT lacks standard bus definitions and classifications, and because "motorcoach" is a commonly used but ambiguous term, the scope of the research and rulemaking described in the action plan remains unclear. As a result, though many of the occupant protection and technology initiatives described in the action plan could prevent or ameliorate crash outcomes such as those in Dolan Springs, it is difficult to assess whether and to what extent the initiatives address medium-size buses and other multistage vehicles. Whether the action plan includes other bus body types has repercussions not only for the passengers who ride in these vehicles, but also for the bus manufacturers, carriers, technology vendors, and other stakeholders that supply and operate them. Finally, the DOT states in the action plan that it intends to improve safety through improved technological methods of data collection and analysis. The NTSB is supportive of this initiative but believes that more basic regulatory changes are needed before any data can be effectively analyzed, interpreted, and used to improve safety.

To eliminate data ambiguity and foster more transparent and accurate public policy decisions, NHTSA and its sister agencies need to collaborate to create uniform regulatory definitions for different bus body types and to base their data systems and other products on these definitions. Little has been done within the DOT to standardize definitions since the NTSB published its bus crashworthiness report 11 years ago. Bus definitions still differ among the FMCSA, the Federal Transit Administration, and NHTSA; and even within agencies, there is confusion as to what a bus is and what distinguishes one bus from another. Therefore, the NTSB concludes that, in the 11 years since the NTSB issued its initial safety recommendations calling for the development of standard regulatory definitions and classifications for the different bus body types, the DOT still does not have standard regulatory definitions. The NTSB recommends that NHTSA, to maintain consistency in bus body classifications and to clarify the scope of bus safety initiatives, develop regulatory definitions and classifications for each of the different bus body types that would apply to all DOT agencies and promote use of the definitions among the bus industry and state governments. This recommendation replaces Safety Recommendations H-99-43 and -44, which the NTSB classifies "Closed—Unacceptable Action/Superseded."

Vehicle Crashworthiness and Occupant Protection

The accident bus had been traveling as a tour bus on a rural road when it rolled over and ejected 15 of its 17 occupants. Medium-size bus bodies and interiors are built with configurations similar to motorcoaches, including large windows with tempered glass glazing, luggage racks that may have protruding video displays, and high-backed seats usually lacking occupant restraints. The accident bus had large window glazing areas that ranged in size from 816–1,530 square inches. Nine of the 10 windows on the bus were broken out during the accident sequence and were a means by which unrestrained passengers were ejected. As with motorcoaches, no Federal regulations or standards require medium-size buses sold or operated in the United States to be equipped with active or passive occupant protection, except at the driver's position.

In addition, the Federal standards on window glazing do not account for advanced glazing materials and bonding techniques for reducing the likelihood of the windows breaking and providing a pathway for ejection. A NHTSA–Transport Canada research program initiated in 2003 to improve glazing and window retention and prevent motorcoach ejections created test procedures to evaluate the effectiveness of glazing materials and bonding techniques. However, it was determined that "significant improvement in roof strength and the structural integrity of windows" was required before realizing the benefits of advanced glazing materials.[12]

The roof of a medium-size bus is not required to meet any Federal regulations regarding roof strength, which is also the case for motorcoaches. In the Dolan Springs accident, the roof above the driver's area was severely damaged and left an opening from which the unbelted driver was likely ejected. However, the roof crush above the passenger compartment was minimal, and there was no intrusion to compromise survivable space, which suggests that fewer fatalities and serious injuries would have occurred had the passengers stayed within their seating areas and not been ejected out the window openings.

In its 1999 bus crashworthiness report, the NTSB concluded that a primary cause of preventable injury in motorcoach accidents involving a rollover, ejection, or both, is occupant motion out of the seat during a collision when no intrusion occurs into the seating area.[13] The NTSB further concluded that the overall injury risk to occupants in motorcoach accidents involving rollover and ejection may be significantly reduced by retaining the occupant in the seating compartment throughout the collision.

The medium-size bus involved in a rollover accident in Lake Placid, Florida, earlier this year, sustained severe roof deflection and crush above both the passenger and driver compartments, resulting in several ejections and three deaths among the unrestrained passengers.[14] The NTSB has found that bus or motorcoach occupants have a better chance of

[12] DOT HS 811 177, p. 33.

[13] NTSB/SIR-99/04.

[14] NTSB investigation HWY-10-FH-009.

survival in a crash when the vehicle remains intact and retains survivable space, and when the occupants remain within their seating compartments throughout the accident sequence.[15]

The NTSB has issued numerous recommendations regarding occupant protection for motorcoaches, several of which originated from the bus crashworthiness special investigation:

H-99-47

In 2 years, develop performance standards for motorcoach occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers.

H-99-48

Once pertinent standards have been developed for motorcoach occupant protection systems, require newly manufactured motorcoaches to have an occupant crash protection system that meets the newly developed performance standards and retains passengers, including those in child safety restraint systems, within the seating compartment throughout the accident sequence for all accident scenarios.

H-99-49

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

H-99-50

In 2 years, issue performance standards for motorcoach roof strength that provide maximum survival space for all seating positions and that take into account current typical motorcoach window dimensions.

H-99-51

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

Safety Recommendations H-99-47 and -50 are currently on the NTSB's Most Wanted List. Safety Recommendation H-99-49 is classified "Open—Acceptable Response" based on correspondence with NHTSA regarding its joint research program with Transport Canada on improving glazing retention and structural integrity requirements for motorcoach-type buses.

In 2008, NHTSA briefed the NTSB on its plans to publish an NPRM on motorcoach occupant restraints. On April 21, 2009, the NTSB reclassified Safety Recommendations

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[15] NTSB/SIR-99/04.

H-99-47, -48, -50, and -51 "Open—Unacceptable Response" following a Board meeting on the Mexican Hat, Utah, accident investigation.[16] These same four recommendations were reiterated to NHTSA on October 27, 2009, following the NTSB's investigation of a motorcoach run-off-the-bridge and rollover accident in Sherman, Texas, that killed 17 passengers.[17] In that investigation, the NTSB concluded that had NHTSA implemented the requirement for motorcoach occupant protection systems in a timely manner following the issuance of Safety Recommendations H-99-47, -48, -50, and -51, more occupants might have been retained within the motorcoach, improving survivability and reducing injuries.

On April 30, 2009, the Secretary of Transportation ordered a full departmental review of motorcoach safety. In November 2009, the DOT published its motorcoach safety action plan,[18] which described a systems-oriented approach for enhancing motorcoach safety. Three of the plan's seven action items—on roof strength, seat belts, and crash avoidance technology—focus on the prevention or amelioration of rollovers. A principal objective of the motorcoach safety action plan is to address outstanding NTSB recommendations on occupant protection, most of which apply to motorcoaches. It is not clear whether the scope of the action plan includes medium-size buses. If the initiatives detailed in the action plan are restricted to motorcoaches, nonschool-related buses with GVWRs in the approximate range of 10,001–26,000 pounds would remain the only class of bus without occupant protection standards. Additionally, though some Federal and state agencies already require the paratransit buses they purchase to comply with the roof strength standards detailed in FMVSS 220, it appears that most do not, thereby placing many of those people who use paratransit at higher risk for injury during accidents. Transit bus passengers may be similarly at risk. In the Washington, D.C., metropolitan area, for example, transit buses are used on urban expressways to transport commuters and those traveling to local airports. A survey of metropolitan transit maps for Los Angeles, Miami, Dallas, and Boston suggests that transit buses are also used on high speed roads in these cities. Because the use of transit buses has expanded from local secondary roads to high speed roads, where crash forces can be greater, the occupant safety standards that apply to these buses should also be improved. The NTSB concludes that because of the lack of Federal standards for occupant protection, roof strength, and advanced window glazing, occupants of motorcoaches and medium-size buses are similarly at risk of ejection during rollover accidents. Therefore, the NTSB recommends that NHTSA, in its rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a GVWR above 10,000 pounds, other than school buses.

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[16] *Motorcoach Rollover Near Mexican Hat, Utah, January 6, 2008*, Highway Accident Report NTSB/HAR-09/01 (Washington, DC: National Transportation Safety Board, 2009).

[17] *Motorcoach Run-Off-the-Bridge and Rollover, Sherman, Texas, August 8, 2008*, Highway Accident Report NTSB/HAR-09/02 (Washington, DC: National Transportation Safety Board, 2009).

[18] DOT HS 811 177.

Luggage Racks

During the accident sequence, the overhead luggage racks on the left and right sides of the bus detached from their anchorages. The luggage rack on the right side was found detached from the roof above rows 4 and 6. In addition, all the screw attachments to the sidewalls had been pulled away. The roof attachments for the luggage rack on the left side remained attached, but the rack was completely detached from the sidewalls.

The NTSB also documented luggage rack failures in the 2008 rollover accident in Sherman, Texas, in which the overhead luggage rack on the right side of the motorcoach failed at the anchorage points and became completely detached.[19] The luggage rack fell diagonally across the aisle onto the passengers and blocked the aisle adjacent to the third and fourth row of seats as well as the right side emergency window exits. The fallen overhead luggage rack obstructed the evacuation route for those who were ambulatory and, based on interview evidence, impeded the efforts of first responders to evacuate injured passengers. As a result, the NTSB made the following recommendations to NHTSA on October 27, 2009:

> <u>H-09-23</u>
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> Develop performance standards for newly manufactured motorcoaches to require that overhead luggage racks remain anchored during an accident sequence.
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> <u>H-09-24</u>
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> Develop performance standards for newly manufactured motorcoaches that prevent head and neck injuries from overhead luggage racks.

On March 15, 2010, NHTSA formally responded to these recommendations and reiterated the agency's commitment to improving motorcoach safety. NHTSA described roof crush and rollover tests it has performed on motorcoaches since 2008 in preparation for possible rulemaking on new roof strength and occupant protection standards. NHTSA maintained that Safety Recommendations H-09-23 and -24 would be suitably addressed in its current research and rulemaking plans.

In the Dolan Springs accident, there was no indication that the detached luggage racks impeded evacuation of the injured. However, as in the Sherman accident, NTSB investigators found evidence of occupant contact marks on the undersides of the overhead luggage racks on both sides of the cabin. During NHTSA's 2008 rollover tests on four motorcoaches, luggage rack failure exposed sharp metal edges, presenting additional sources of passenger injury.[20] In the July 2009 tests, unprotected racks caused head injuries to the unrestrained dummy.

As is the case with motorcoaches, there are currently no performance standards for overhead luggage racks on medium-size buses. It is evident from both the Sherman and Dolan

[19] NTSB/HAR-09/02.

[20] *NHTSA ECE Regulation 66-Based Research Test of Motorcoach Roof Strength*, Final Report, ECE66-MGA2007-001 (Washington, DC: National Highway Traffic Safety Administration and Economic Commission for Europe, May 2008).

Springs accidents that the strength of luggage rack anchors should be considered as part of any systematic evaluation of bus occupant safety. Although it is not specifically known when the luggage racks on the accident bus failed, it is important to note that they failed despite minimal deformation to the roof structure. It is clear from the way the luggage racks were mounted above the seatbacks that—had the occupants been restrained in their seats—the failure of the racks might have resulted in head injuries and hampered egress from the vehicle. The NTSB concludes that the detachment of overhead luggage racks presents a potential injury source for both restrained and unrestrained bus passengers. Because of this potential hazard, the NTSB recommends that NHTSA develop performance standards for all newly manufactured buses with a GVWR above 10,000 pounds to require that overhead luggage racks are constructed and installed to prevent head and neck injuries and remain anchored during an accident sequence. This recommendation replaces Safety Recommendations H-09-23 and -24, both of which the NTSB classifies "Closed—Superseded."

Crash Mitigation Technology

The physical evidence at the accident scene included several feet of tire marks indicating the motion of the bus as it traveled off of the roadway onto the right shoulder, back across the roadway, and into the center median. The NTSB conducted a series of computer simulations based on these marks to study vehicle dynamics and better understand the circumstances that led to the accident. The simulations suggested the following order of events:

- First, the accident bus likely underwent all or part of a sinusoidal[21] motion prior to traveling on the right shoulder. This movement is consistent with a scenario in which a bus traveling in the right lane drifts or is steered into the left lane, then is steered back hard to the right, causing it to veer onto the right shoulder; and it is also consistent with the driver's statement that he was initially traveling in the right lane.

- Second, as the bus was steered back toward the roadway from the right shoulder, it approached the limits of its cornering capability, which changed its handling characteristics. The bus began to develop a rapid counterclockwise rotation, or spinout, which the driver could not arrest even with rapid countersteering to the right as the bus reentered the roadway. The development of this spinout immediately preceded the bus's departure from the left side of the road into the center median.

- Finally, the rollover was caused by a combination of the bus sliding sideways as it entered the center median and the tires digging into the sandy soil.

Of particular interest in the simulations were the handling changes and the subsequent spinout of the bus as it traveled on the right shoulder of the roadway—a situation that could make vehicle recovery difficult for all but the most skilled drivers. The challenge in controlling a vehicle as it approaches the limits of tire/road friction is that its response can change, tending toward oversteer (spinout) or understeer (plowing); and the lag time of the vehicle's response can lengthen, leading to a situation where the driver's learned responses to normal driving situations

[21] "Sinusoidal" refers to an oscillation, such as a back-and-forth sideways motion.

do not apply. When a driver encounters these changes during a panic situation, it adds to the likelihood that he or she will lose control of the vehicle.

For commercial vehicles over 10,000 pounds GVWR, stability control systems are generally divided into two types:

- Roll stability control, which is primarily designed to prevent on-road rollover; and
- Yaw stability control, which is primarily designed to address directional instability.

Roll stability control systems work by monitoring lateral acceleration to determine when rollover is imminent and applying braking to reduce the lateral acceleration. Yaw stability control systems use driver steering input and measured yaw rate as well as lateral acceleration to determine the proper differential braking to reduce directional instabilities, thereby reducing the tendency of a vehicle to understeer or oversteer during an emergency maneuver as it approaches the limits of its traction.

Several studies have shown stability control systems to be highly effective in preventing single-vehicle accidents involving automobiles and sport utility vehicles (SUV), and NHTSA requires that all vehicles with GVWRs of 10,000 pounds or less be equipped with stability control systems by the 2012 model year.[22,23,24] NHTSA estimates that the installation of stability control systems will reduce all single-vehicle crashes of passenger cars by 34 percent and single-vehicle crashes of SUVs alone by 59 percent, with a much greater reduction in rollover crashes. Once all light vehicles are equipped, the agency estimates that stability control systems could save 5,300–9,600 lives per year and prevent 156,000–238,000 injuries in all types of crashes.[25]

The NTSB simulated stability control systems on the accident bus to determine whether they might have allowed the driver to maintain control. Inclusion of stability control in the simulation reduced the changes in vehicle handling as the bus traveled over the right shoulder of the road—which might have made it easier for the driver to maintain control of the bus as he steered away from the right shoulder. The simulations further indicated that braking by the stability control systems would have slowed the bus, which would have given the driver slightly more time to react to the situation and lowered lateral acceleration. Based on accident simulations, the NTSB concludes that the likelihood of the driver losing control and crashing would have been lower had the accident bus been equipped with a stability control system.

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[22] (a) J. Dang, *Statistical Analysis of the Effectiveness of Electronic Stability Control (ESC) Systems*, Final Report, DOT HS 810 794 (Washington, DC: U.S. Department of Transportation, July 2007). (b) P. Green and J. Woodrooffe, *The Effect of Stability Control on Motor Vehicle Crash Prevention*, UMTRI-2006-12 (Ann Arbor, Michigan: University of Michigan Transportation Research Institute, April 2006).

[23] *Federal Motor Vehicle Safety Standards (FMVSS) and Electronic Stability Control (ESC) Systems, Controls and Displays*, Final Rule, Docket No. NHTSA-2007-27662 (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, April 2007).

[24] *Federal Regulatory Impact Analysis: FMVSS No. 126, Electronic Stability Control Systems*, Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis (Washington, DC: National Highway Traffic Safety Administration, March 2007).

[25] FMVSS, ESC Final Rule.

The NTSB has advocated the study and implementation of technology to aid commercial vehicle drivers in maintaining control of their vehicles since the multiple-fatality incident that occurred near Slinger, Wisconsin, in 1997.[26] In that accident, a doubles truck traveling northbound on U.S. Route 41 in hazardous weather conditions crossed over the median into the southbound lanes. This incursion initiated a series of collisions that resulted in eight fatalities. As a result of this accident, the NTSB issued the following recommendation to NHTSA:

<u>H-98-15</u>

Work, together with the Federal Highway Administration, the American Trucking Associations, the International Brotherhood of Teamsters, and the Motor Freight Carrier Association, to conduct laboratory and truck fleet testing to assess the safety benefits of adding traction control devices to antilock brake systems and report your findings to the National Transportation Safety Board.

The NTSB revisited the potential benefits of vehicle control technology in its investigation of a 2005 multiple-fatality accident near Osseo, Wisconsin,[27] and made the following recommendation to NHTSA:

<u>H-08-15</u>

Determine whether equipping commercial vehicles with collision warning systems with active braking and electronic stability control systems will reduce commercial vehicle accidents. If these technologies are determined to be effective in reducing accidents, require their use on commercial vehicles.

Both Safety Recommendations H-98-15 and H-08-15 are classified “Open—Acceptable Response.”

According to NHTSA, it has conducted statistical research on stability control systems for large-platform buses (above 10,000 pounds GVWR),[28] and there are plans to test a medium-size bus with a GVWR of at least 26,000 pounds, but the agency has so far been unable to identify such a vehicle already equipped with a stability control system. NHTSA officials indicated to the NTSB that the exclusion of medium-size buses in vehicle tests thus far does not preclude them from any potential rulemaking and that stability control could be required on the buses if supported by other research.

According to both General Motors and Starcraft, stability control systems were not offered as options on the accident bus at the time of its manufacture. After contacting NHTSA and several manufacturers of braking systems and stability control systems, the NTSB identified

[26] *Multiple Vehicle Crossover Accident, Slinger, Wisconsin, February 12, 1997,* Highway Accident Report NTSB/HAR-98/01 (Washington, DC: National Transportation Safety Board, 1998).

[27] NTSB/HAR-08/02.

[28] M. daSilva and others, *Crash Problem Definition and Safety Benefits Methodology for Stability Control for Single-Unit Medium and Heavy Trucks and Large-Platform Buses*, DOT HS 811 099 (Washington, DC: National Highway Traffic Safety Administration, 2009).

only one bus/van between 10,000–33,000 pounds GVWR sold in the United States and equipped with a stability control system.[29] Two major manufacturers of stability control systems for vehicles equipped with air brakes stated that their systems could be adapted for use in medium-size buses.

Research has already demonstrated that stability control is highly effective in reducing rollover and single-vehicle crashes in passenger vehicles and SUVs. The NTSB recognizes that specific vehicle characteristics could affect the overall effectiveness of these systems; however, the results of simulations suggest that there are potential benefits in equipping vehicles, such as medium-size buses, with stability control systems. The motorcoach safety action plan indicates that the agency's goal is to develop performance standards for large trucks and motorcoaches if this objective is supported by research. The NTSB supports this goal but is concerned that the development of stability control systems and standards for medium-size buses is currently lagging behind that for other commercial vehicles. Therefore, the NTSB recommends that NHTSA develop stability control system performance standards applicable to newly manufactured buses with a GVWR above 10,000 pounds. Once the performance standards have been developed, the NTSB recommends that NHTSA require the installation of stability control systems in all newly manufactured buses in which this technology could have a safety benefit.

Event Data Recorders

The Chevrolet engine on the accident bus was equipped with an electronic control module (ECM) that functioned as the engine computer; but, it was not designed to be a data recorder and was not capable of recording parameters such as vehicle speed, engine rpm, brake use, or percent throttle. The bus was not equipped with any form of event data recorder (EDR). Because event data were unavailable, the NTSB had to rely on simulation-based estimates of steering wheel angle, lateral acceleration, vehicle speed, and yaw rate to determine the stability of the bus throughout the accident sequence. Although the NTSB's computer model appeared to correlate well with the physical evidence, a more robust reconstruction, based on fewer estimates, would have been possible with the retrieval of event data. The NTSB concludes that the availability of recorded event data would have resulted in a more complete account of the preaccident events leading to the rollover of the accident bus.

In its bus crashworthiness report, the NTSB described the importance of event data in the reconstruction of accidents and the continued development of bus occupant protection systems, and issued the following recommendations to NHTSA:[30]

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

[29] The Sprinter van, a vehicle with a GVWR of 11,030 pounds and equipped with hydraulic brakes, is sold with a stability control system. It is manufactured by Mercedes Benz. Bosch sells a stability control system in Europe for a vehicle with a GVWR of 14,030 pounds that is equipped with hydraulic brakes.

[30] NTSB/SIR-99/04.

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

Several positive developments have occurred since the issuance of these recommendations, among which are the following:

- Establishment of a truck and bus EDR working group by NHTSA in 2000;[31]

- Publication of IEEE Standard P1616, "Standard for Motor Vehicle Event Data Recorders," in 2005 and the SAE International (SAE) Recommended Practice (RP) J1698 in 2003 to establish a common format for displaying and presenting postdownloaded crash-related data recorded and stored within electronic components currently installed in many light-duty vehicles;

- Publication of SAE RP J1698/1 in 2003 to provide definitions for event-related data items;

- Publication of SAE RP J1698/2 in 2004 to define a common method for extracting event data;[32]

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

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

- Publication of RP 1214 by the American Trucking Associations in 2004 to provide guidelines for the collection, storage, and retrieval of event-related data from electronic control units in commercial vehicles;[33] and

- Publication of requirements for EDR components, hardware, software, sensors, and databases by the Federal Highway Administration in 2004 as part of the FMCSA's Commercial Vehicle Safety Technology Diagnostics and Performance Enhancement Program.[34]

In June 2010, the SAE Truck and Bus Event Data Recorder Committee completed RP J2728, which serves as a base standard for heavy vehicle event data recorders (HVEDR) and applies to heavy-duty vehicles[35] over 10,000 pounds that are designed or required to comply with the FMVSSs. RP J2728 provides design and performance requirements necessary to comply with the development of a "tier 1" (minimum capabilities) HVEDR. Subsequent documents are envisioned to significantly expand on recommended capabilities. NHTSA anticipates making a regulatory decision on HVEDRs in the near future. According to NHTSA, it will determine at that time whether it will apply to motorcoaches, to school buses, or to all heavy vehicles.[36]

Despite the work that has been done since the NTSB first issued Safety Recommendations H-99-53 and -54, there is still no requirement for the installation and use of EDRs on motorcoaches and school buses. The NTSB reiterated these recommendations in the investigation of a 2007 motorcoach ramp override accident in Atlanta, Georgia, that killed seven passengers.[37] In that accident, the NTSB determined that EDR data would have yielded information on vehicle parameters and driver actions prior to the accident, as well as on vehicle dynamics throughout the accident sequence—which would have been valuable in reconstructing and evaluating occupant kinematics, injury exposure, and the potential benefits of occupant protection devices and systems. These two recommendations were again reiterated in the NTSB's 2009 special investigation of pedal misapplication in heavy vehicles, a report that focused primarily on school buses.[38] The NTSB concluded that the presence of EDRs in heavy vehicles would provide essential and specific information regarding the causes and mechanisms of pedal misapplication and unintended acceleration; Safety Recommendations H-99-53 and -54 were reclassified "Open—Unacceptable Response" due to NHTSA's failure to require the use of EDRs on buses.

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[33] *American Trucking Associations Technology and Maintenance Council Guidelines for Event Recording: Collection, Storage, and Retrieval*, Recommended Practice 1214 (Alexandria, Virginia: American Trucking Associations, January 2004).

[34] See <http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14146_files/14146.pdf>, accessed April 14, 2010.

[35] The term "heavy-duty vehicle" refers to vehicles equipped with one or both of the SAE J1708/J1587 or SAE J1939 communication networks.

[36] Email correspondence to the NTSB from the Acting Director, Office of Strategic Planning, NHTSA, March 19, 2010.

[37] *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).

[38] *Pedal Misapplication in Heavy Vehicles*, Highway Special Investigation Report NTSB/SIR-09/02 (Washington, DC: National Transportation Safety Board, 2009).

Safety Recommendation H-99-53 specifies that EDRs be required for school buses and motorcoaches. However, as illustrated by the Dolan Springs accident, EDR data would also be useful in the reconstruction of preaccident events and crash dynamics for medium-size buses. Because SAE RP J2728 is designed to address the application of EDRs in vehicles over 10,000 pounds GVWR, it should be possible for NHTSA to include all buses above 10,000 pounds GVWR in any regulatory requirements based on RP J2728. The NTSB concludes that having EDRs on all buses above 10,000 pounds GVWR would greatly increase the understanding of crash causation and be helpful in further establishing design requirements for crashworthiness and occupant protection systems. As a result, the NTSB recommends that NHTSA require that all buses above 10,000 pounds be equipped with on-board recording systems that: (1) 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); (2) record status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy; (3) record data at a sampling rate sufficient to define vehicle dynamics and be capable of preserving data in the event of a vehicle crash or an electrical power loss; and (4) are mounted to the bus body, not the chassis, to ensure recording of the necessary data to define bus body motion. This recommendation replaces Safety Recommendation H-99-53, which the NTSB classifies "Closed—Unacceptable Action/Superseded."

To summarize, as a result of its investigation of the Dolan Springs accident, the National Transportation Safety Board makes the following new recommendations to the National Highway Traffic Safety Administration:

> Require new commercial motor vehicles with a gross vehicle weight rating above 10,000 pounds to be equipped with lane departure warning systems. (H-10-01)
>
> To maintain consistency in bus body classifications and to clarify the scope of bus safety initiatives, develop regulatory definitions and classifications for each of the different bus body types that would apply to all U.S. Department of Transportation agencies and promote use of the definitions among the bus industry and state governments. (H-10-02) (This recommendation supersedes Safety Recommendations H-99-43 and -44 and is classified "Open—Unacceptable Response.")
>
> In your rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a gross vehicle weight rating above 10,000 pounds, other than school buses. (H-10-03)
>
> Develop performance standards for all newly manufactured buses with a gross vehicle weight rating above 10,000 pounds to require that overhead luggage racks are constructed and installed to prevent head and neck injuries and remain anchored during an accident sequence. (H-10-04) (This recommendation supersedes Safety Recommendations H-09-23 and -24.)

> Develop stability control system performance standards applicable to newly manufactured buses with a gross vehicle weight rating above 10,000 pounds. (H-10-05)
>
> Once the performance standards from Safety Recommendation H-10-05 have been developed, require the installation of stability control systems in all newly manufactured buses in which this technology could have a safety benefit. (H-10-06).
>
> Require that all buses above 10,000 pounds gross vehicle weight rating be equipped with on-board recording systems that: (1) 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); (2) record status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy; (3) record data at a sampling rate sufficient to define vehicle dynamics and be capable of preserving data in the event of a vehicle crash or an electrical power loss; and (4) are mounted to the bus body, not the chassis, to ensure recording of the necessary data to define bus body motion. (H-10-07) (This recommendation supersedes Safety Recommendation H-99-53 and is classified "Open—Unacceptable Response.")

In addition, as discussed herein and in the Dolan Springs accident investigation report, the NTSB classifies the following previously issued recommendations:

- Safety Recommendation H-99-43 to the U.S. Department of Transportation (previously classified "Open—Acceptable Alternate Response") is classified "Closed—Unacceptable Action/Superseded." This recommendation is replaced by Safety Recommendation H-10-02.

- Safety Recommendation H-99-44 to the U.S. Department of Transportation (previously classified "Open—Acceptable Response") is classified "Closed—Unacceptable Action/Superseded." This recommendation is replaced by Safety Recommendation H-10-02.

- Safety Recommendation H-99-53 to the National Highway Traffic Safety Administration (previously classified "Open—Unacceptable Response") is classified "Closed—Unacceptable Action/Superseded." This recommendation is replaced by Safety Recommendation H-10-07.

- Safety Recommendation H-09-23 to the National Highway Traffic Safety Administration (previously classified "Open—Initial Response Received") is classified "Closed—Superseded." This recommendation is replaced by Safety Recommendation H-10-04.

- Safety Recommendation H-09-24 to the National Highway Traffic Safety Administration (previously classified "Open—Initial Response Received") is classified "Closed—Superseded." This recommendation is replaced by Safety Recommendation H-10-04.

In response to the new recommendations in this letter, please refer to Safety Recommendations H-10-01 through -07. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Member SUMWALT concurred in these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
H-10-001	1	SS-13-01	7/3/2013	Crashes involving Single-Unit Trucks that Resulted in Injuries and Death	N/A	N/A	N/A

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
H-10-003	1	HAR-15-03	11/17/2015	Truck-Tractor Semitrailer Median Crossover Collision With Medium-Size Bus on Interstate 35, Davis, Oklahoma, September 26, 2014	Davis	OK	9/26/2014

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
H-10-007	1	HAR-15-01	7/14/2015	Truck-Tractor Double Trailer Median Crossover Collision With Motorcoach and Postcrash Fire on Interstate 5, Orland, California, April 10, 2014	Orland	CA	4/10/2014
H-10-007	2	HAR-15-03	11/17/2015	Truck-Tractor Semitrailer Median Crossover Collision With Medium-Size Bus on Interstate 35, Davis, Oklahoma, September 26, 2014	Davis	OK	9/26/2014
H-10-007	3	SIR-18-02	6/21/2018	Selective Issues in School Bus Transportation Safety: Crashes in Baltimore, Maryland, and Chattanooga, Tennessee	Baltimore Chattanooga	MD TN	11/1/2016 11/21/2016