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**National Highway
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Memorandum

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Subject: "NHTSA's Approach to Motorcoach Safety"

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From: Roger A. Saul Roger A Saul
Director, Office of Crashworthiness Standards

Reply to
Attn of: NVS-110

To: NHTSA Docket 2007-28793

Attached, please find "NHTSA's Approach to Motorcoach Safety".

NHTSA's Approach to Motorcoach Safety

The goal of this paper is to present a comprehensive review of motorcoach[1] safety issues and the course of action the National Highway Traffic Safety Administration will pursue to most expediently address them. Improvements to motorcoach safety are grouped by the following categories: prevention, mitigation, and evacuation.

I. Background

Motorcoaches fall under the category of buses in the Federal Motor Vehicle Safety Standards (FMVSS). FMVSS No. 217, "Bus emergency exits and window retention and release," specifies a series of dimensional and physical requirements for bus emergency exits and windows. The window retention testing required for this standard is a quasi-static test. This standard became effective on September 1, 1973, for all new buses with the exception of school buses (unless they were voluntarily installed).[2] The standard has not substantially changed for buses since its inception in 1972. In addition to FMVSS No. 217, motorcoaches must comply with the following crashworthiness standards: FMVSS No. 208, "Occupant crash protection," FMVSS No. 209, "Seat belt assemblies," FMVSS No. 210, "Seat belt assembly anchorages," and FMVSS No. 302, "Flammability of interior materials," among other standards. FMVSS Nos. 208, 209, and 210 presently apply to the driver's seat only.

In Europe, seven ECE regulations apply to the passive safety of motorcoaches: ECE 14 (Safety-Belt Anchorages), ECE 16 (Safety-Belts for Occupants of Power-Driven Vehicles), ECE 36 (Construction of Public Service Vehicles), ECE 52 (Construction of Small Capacity Public Service Vehicles), ECE 66 (Strength of Superstructure), ECE 80 (Strength of Seats and their Anchorages[3]), and ECE 118 (Burning Behavior of Materials Used In Interior Construction).

In Australia, all motorcoaches sold must comply with the Australian Design Rules (ADR's) in addition to the ECE requirements. The ADR's set out design standards for vehicle safety and emissions. The ADR's pertaining to motorcoaches are ADR 3 (Seats and Seat Anchorages), ADR 4 (Seat Belts), ADR 5 (Anchorages for Seat Belts and Child Restraints), ADR 66 (Seat Strength, Seat Anchorage and Padding in Omnibuses), ADR 68 (Occupant Protection in Buses), and ADR 69 (Full Frontal Impact Occupant Protection).

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[1] Throughout this report, motorcoach refers to inter-city transport buses.
[2] Provisions in FMVSS No. 217 place additional requirements on school buses.
[3] Testing of seatbelt-ready seats is covered under this regulation.

A. Statistics

Motorcoach transportation has been a safe form of transportation in the United States. Over the past ten years (1996-2005) there have been 48 fatal motorcoach crashes. During this period, on average, 14 fatalities have occurred annually to occupants of motorcoaches in crash and rollover events, with about 2 of the fatalities being drivers. Approximately 29% of the fatal crashes resulted in rollover. Ejection of passengers from motorcoaches accounts for approximately 56% of passenger fatalities. Among all motorcoach crashes from 1996-2005, 65% were single vehicle events and involved running off the road, hitting roadside objects, or rolling over.

Motorcoach Fatalities, Drivers and Passengers (FARS 1996-2005)

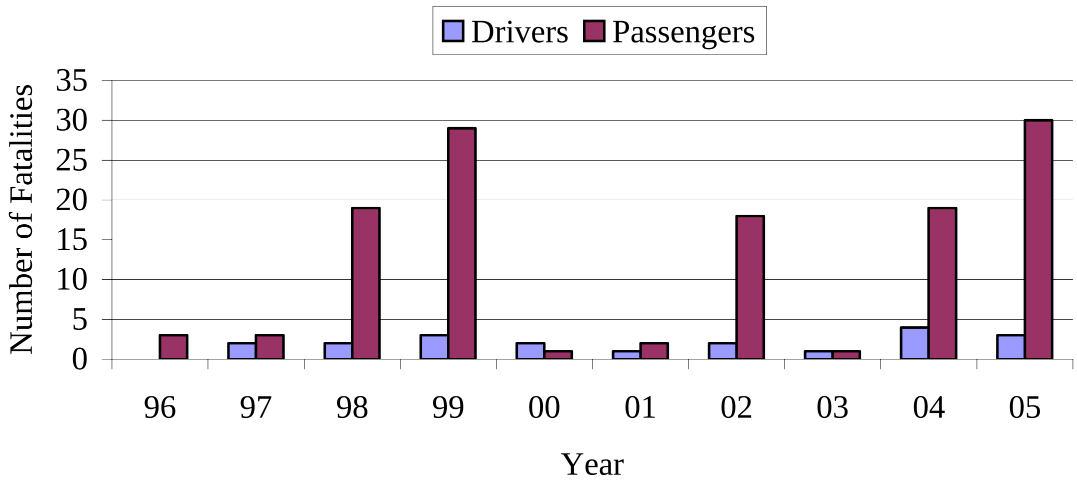

Figure 1: Motorcoach fatalities.

Figure 1 shows motorcoach fatalities from 1996-2005. The increased fatalities for the years 1999, 2004, and 2005 each resulted from a single event with a large number of fatalities. The majority of fatalities in 1999 resulted from a crash in Louisiana in which the motorcoach struck a guardrail, jumped a ravine, and struck the embankment at a high speed. There was no rollover involved in this event. This crash resulted in 22 fatalities, all of which were passengers. The majority of fatalities in 2004 resulted from a crash in Arkansas, which involved the motorcoach hitting a highway signpost and subsequently rolling over. This crash resulted in 15 fatalities, including the driver. All 14 passengers who died in this crash were ejected; the driver was not ejected. The majority of fatalities in 2005 resulted from a motorcoach fire in Wilmer, Texas. This bus was carrying evacuees from a nursing home during the Hurricane Rita evacuation. The 23 fatalities, all of which were passengers, were caused by a tire fire that subsequently carried into the passenger compartment of the bus. These events show that while motorcoach crashes may be relatively rare, they can cause a significant number of fatal or serious injuries for a single event.

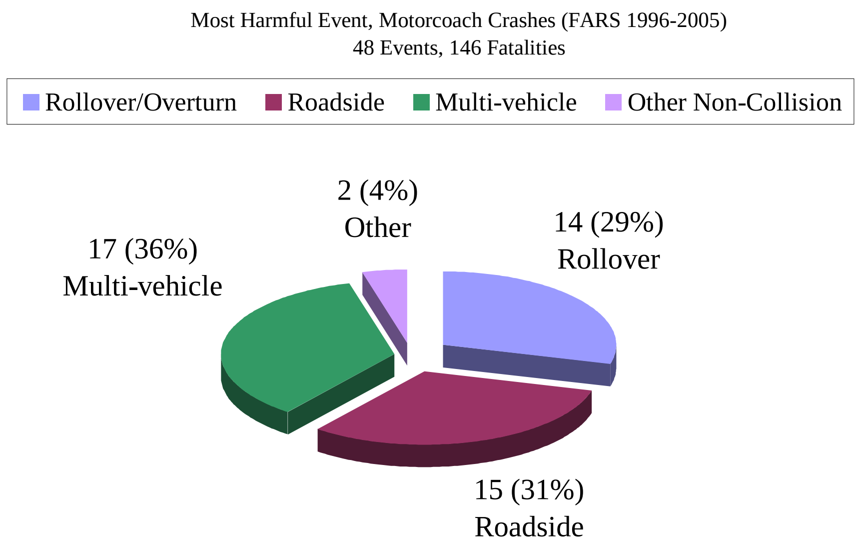

Figure 2: Motorcoach crashes by most harmful event.

Figure 2 shows motorcoach crashes by most harmful event over the years 1996-2005. Multi-vehicle crashes, roadside objects, and rollover/overturn are all within 7% of each other for percentage of fatal crashes where these are the most harmful events.

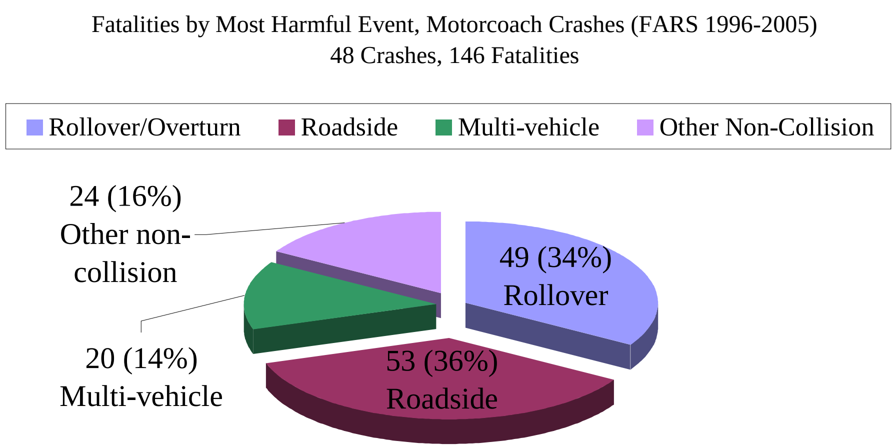

Figure 3: Motorcoach fatalities by most harmful event.

Figure 3 shows the motorcoach fatalities by most harmful event. Running off the road and striking a roadside object was the most common most harmful event, leading to 36% of the fatalities. Rollover/overturn was the most harmful event for 34% of the fatalities. The trends for first harmful event were similar, with striking a roadside object being the first harmful event for 40% of the fatalities, and rollover/overturn being the first harmful event leading to 30% of the fatalities.

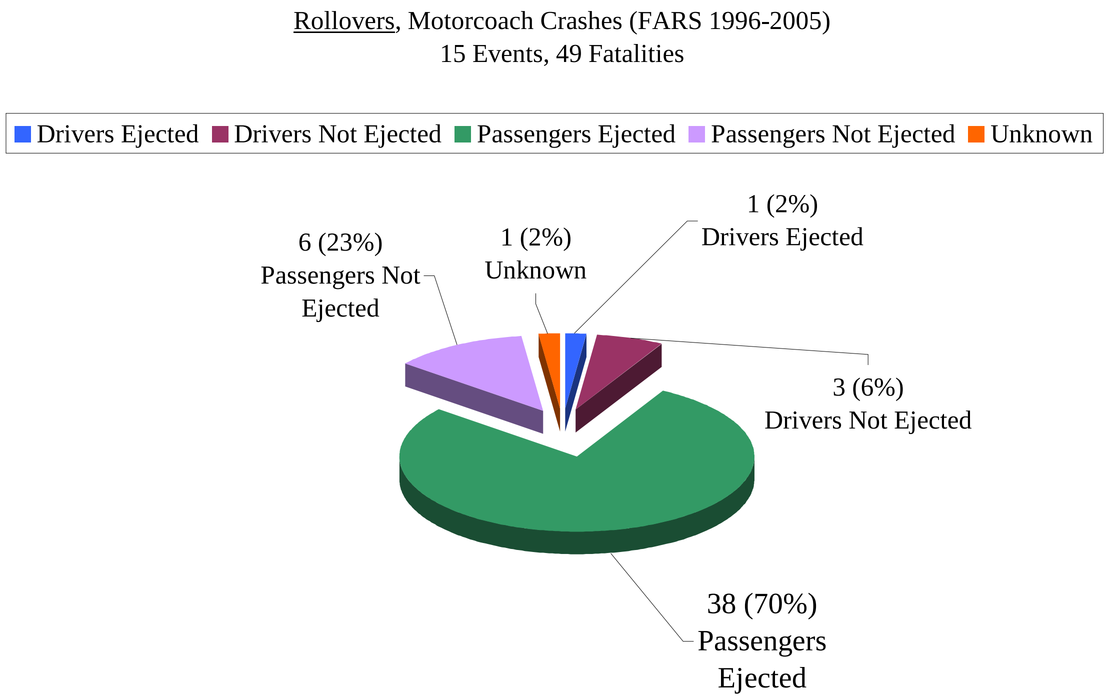

Figure 4: Ejection fatalities in rollover crashes.

Figure 4 shows fatalities in motorcoach rollover crashes[4]. In rollover events, 70% of passenger fatalities were ejections. One driver involved in a rollover crash was ejected.

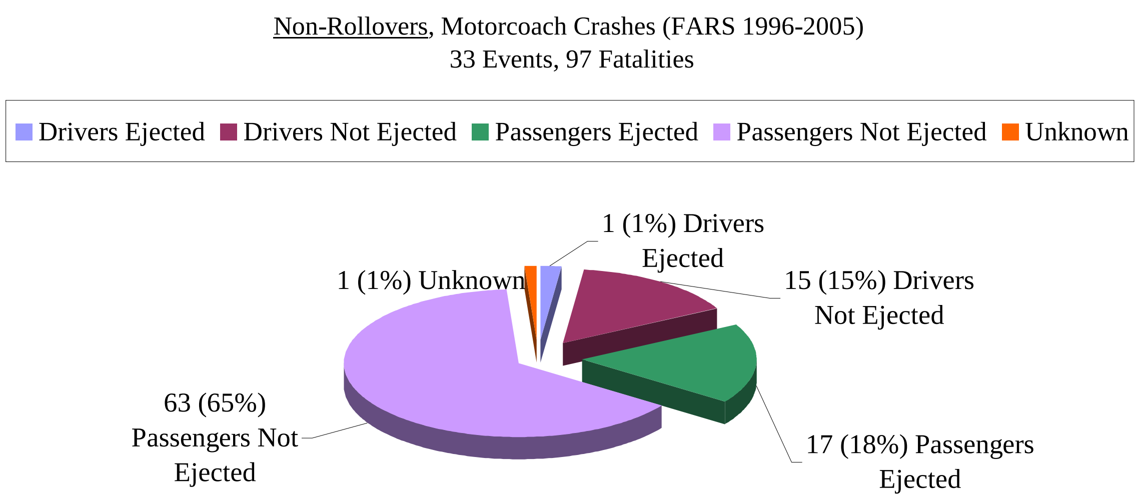

Figure 5: Ejection fatalities in non-rollover crashes.

[4] In one rollover crash, impact with a tree was the most harmful event. That event has been included in Figure 4 even though it was included in the "Other" category in Figure 2.

Figure 5 shows fatalities in non-rollover crashes. Unlike in rollovers, only a small percentage of the passengers and driver fatalities are ejected. There were two cases of ejected driver fatalities in non-rollover crashes.

In addition to these fatal crashes, over the past ten years there have been several recalls conducted by manufacturers that pertain to fires. Recalls by Motor Coach Industries (MCI), Van Hool, and Prevost due to turbocharger failure, battery equalizer, electrical shorts, and/or auxiliary heater fires have totaled over 13,000 motorcoaches[5]. In addition, Detroit Diesel conducted a recall of over 12,000 engines[6], many of which were installed in motorcoaches. Although there were no reported injuries related to these fires, the tragic Wilmer, Texas, incident illustrates the devastating results that can occur when a fire erupts on a motorcoach.

B. NTSB Safety Recommendations

NTSB has made a number of recommendations to the agency for improved safety of motorcoach passengers. These safety recommendations mainly apply to crashworthiness issues such as occupant protection and roof crush. Some recommendations are on its "Most Wanted" list of safety improvements[7]. This section provides a listing of NTSB recommendations and descriptions of the crashes that led to the recommendations.

The following six safety recommendations were issued in conjunction with a 1999 NTSB Highway Special Investigation Report[8]. NTSB initiated this special investigation to determine whether additional measures should be taken to better protect bus occupants. It examined motorcoach crashworthiness issues through the analysis of 40 bus crashes and through information gathered at NTSB's August 12, 1998 public hearing.

H-99-43: 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 FMVSS.

H-99-47 (MW): 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.

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[5] Motor Coach Industries (MCI) conducted three recalls totaling 8,384 coaches, which were due to defects such as turbocharger failures, electrical shorts, and auxiliary heater fires. Van Hool conducted four recalls totaling 2,338 coaches, which were due to defects such as turbocharger failures, battery equalizer fires, and auxiliary heater fires. Prevost conducted four recalls totaling 2,758 coaches, which were due to defects such as turbocharger failures and battery equalizer failures.

[6] The Detroit Diesel engine recall was due to turbocharger failures.

[7] Designated as "(MW)" in the listing.

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

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 (MW): 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.

The next five safety recommendations resulted from a 2005 motorcoach fire.[9] On September 23, 2005, a 1998 Motor Coach Industries 54-passenger motorcoach was traveling on an Interstate highway near Wilmer, TX as part of the evacuation in anticipation of Hurricane Rita. It was carrying 44 assisted living facility residents and nursing staff. A motorist noticed that the right-rear tire hub was glowing red hot and alerted the motorcoach driver, who then stopped the bus. The driver and nursing staff exited the motorcoach and observed flames emanating from the right-rear wheel well. As an evacuation of the motorcoach was initiated, heavy smoke and fire quickly engulfed the entire vehicle. Twenty-three passengers were fatally injured and 2 were seriously injured.

H-07-04: Develop a Federal Motor Vehicle Safety Standard to provide enhanced fire protection of the fuel system in areas of motorcoaches and buses where the system may be exposed to the effects of a fire.

H-07-05: Develop a Federal Motor Vehicle Safety Standard to provide fire-hardening of exterior fire-prone materials, such as those in areas around wheel wells, to limit the potential for flame spread into a motorcoach or bus passenger compartment.

H-07-06: Develop detection systems to monitor the temperature of wheel well compartments in motorcoaches and buses to provide early warning of malfunctions that could lead to fires.

[9] In addition to the Wilmer, Texas incident, on July 15, 2003, a motorcoach fire occurred at the Charles Town Races and Slots in Charles Town, WV, but was not the subject of an NTSB investigation. It was believed that the cause of the fire was a seized brake resulting in the rear tire sliding along the roadway and catching fire. All 47 occupants of the bus escaped through the front door and emergency exit windows, but several injuries occurred.

H-07-07: Evaluate the need for a Federal Motor Vehicle Safety Standard that would require installation of fire detection and suppression systems on motorcoaches.

H-07-08: Evaluate current emergency evacuation designs of motorcoaches and buses by conducting simulation studies and evacuation drills that take into account, at a minimum, acceptable egress times for various post-accident environments, including fire and smoke; unavailable exit situations; and the current above-ground height and design of window exits to be used in emergencies by all potential vehicle occupants.

The next two safety recommendations were issued following a crash in Pennsylvania[10]. A 1997 MCI 47-passenger motorcoach ran off the highway into an emergency parking area, where it struck the back of a parked semi tractor-trailer. The driver and 6 passengers were killed. A major safety issue identified in this accident was the lack of motorcoach emergency interior lighting and retro reflective signage. According to passengers, the bus was "pitch black" after the accident and passengers had difficulty finding the emergency exits, thus slowing the evacuation. When emergency responders arrived, injured passengers were trapped within the bus, and the interior of the bus was completely dark.

H-00-01: Revise the FMVSS to require that all motorcoaches be equipped with emergency lighting fixtures that are outfitted with a self-contained independent power source.

H-00-02: Revise the FMVSS to require the use of interior luminescent or exterior retro-reflective material, or both, to mark all emergency exits in all motorcoaches.

The following safety recommendation was issued in conjunction with 1999 NTSB investigations[11] of two accidents. The one that led to the safety recommendation occurred on July 29, 1997. A 1985 Transportation Manufacturing Corporation (TMC) motorcoach, occupied by a driver and 34 passengers, drifted off the side of an Interstate highway, down an embankment, and into a river where it came to rest on its left side. One passenger sustained fatal injuries; the driver and three passengers sustained serious injuries. In the crash, the roof emergency escape hatch was almost completely submerged, preventing its use for egress. Several passengers reported that they had difficulty evacuating the bus because the emergency window would not remain open.

H-99-9 (MW): Revise the Federal Motor Vehicle Safety Standard (FMVSS) No. 217, "Bus Emergency Exits and Window Retention and Release," to require that other than floor-level emergency exits can be easily opened and remain open during an emergency evacuation when a motorcoach is upright or at unusual attitudes.

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[10] NTSB Accident No. HWY-98-MH-033, Burnt Cabins, Pennsylvania, June 20, 1998.

[11] National Transportation Safety Board. 1999. *Selective Motorcoach Issues.* Highway Special Investigation Report NTSB/SIR-99/01. Washington, DC.

The next safety recommendation resulted from a crash in 2003 when a 1992 Neoplan USA Corporation 49-passenger motorcoach traveling on an interstate highway drifted onto the shoulder and struck the rear of a 1988 Peterbilt semi tractor-trailer[12]. Eight motorcoach passengers sustained fatal injuries. The driver and six of the fourteen passengers on board received serious injuries. Failure of the motorcoach seat anchorages contributed to the severity of the injuries.

H-05-01: Develop performance standards for passenger seat anchorages in motorcoaches.

The safety recommendation below was issued following the crash of a motorcoach in which the driver broke hard, lost control on a highway with wet road conditions, crossed the median, entered the opposing traffic lanes, and collided with another vehicle[13]. Five motorcoach passengers sustained fatal injuries. The minimum tread depths on the motorcoach's drive axle tires and differing tread depths on its front and rear tires were found to reduce the friction available to the motorcoach.

H-05-17: Conduct testing on the effects of differing tread depths for the steer and drive axle tires.

The last three safety recommendations listed in this section were issued in conjunction with a 2001 NTSB Highway Special Investigation Report.[14] Between 1999 and 2000, NTSB investigated nine rear-end collisions in which 20 people died and 181 were injured. Common to all nine accidents was vehicle driver's degraded perception of traffic conditions ahead. NTSB concluded that collision warning devices could potentially have helped alert the drivers to the vehicles ahead so that they could slow down their vehicles and either prevented or mitigated the circumstances of the collisions.

H-01-06: Complete rulemaking on adaptive cruise control and collision warning system performance standards for new commercial vehicles. At a minimum, these standards should address obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning.

H-01-07: After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system.

H-01-09: Develop and implement, in cooperation with the Federal Highway Administration, the Intelligent Transportation Society of America, and the truck,

[12] National Transportation Safety Board, 2005, Highway Accident Report NTSB/HAR-05/01, Motorcoach Run-Off-The-Road Accident, Tallulah, Louisiana, October 13, 2003.
[13] National Transportation Safety Board, 2005, Highway Accident Report, NTSB/HAR-05/02 Motorcoach Median Crossover With Sport Utility Vehicle, Hewitt, Texas, February 14, 2003.
[14] National Transportation Safety Board, 1999, Highway Special Investigation Report NTSB/SIR-01/01. Washington, DC.

motorcoach, and automobile manufacturers, a program to inform the public and commercial drivers on the benefits, use, and effectiveness of collision warning systems and adaptive cruise controls.

C. Applicable Research

In April 2003, the National Highway Traffic Safety Administration (NHTSA) and Transport Canada entered into a joint program that was completed in September 2006[15]. This program focused on improving glazing and structural integrity on motorcoaches to prevent ejections, using standard coach windows and different variations of glazing and bonding techniques. An overview follows.

Through computer simulation using the ECE Regulation 66 (ECE R.66) rollover test, a joint program between NHTSA and Transport Canada has established the forces that motorcoach occupants exert on the window during rollover events, and the impact forces applied to the roof of the motorcoach. The ECE R.66 rollover test places the bus on a level surface 800 mm (31.5 inches) above a flat surface, and the bus is tipped over on its side to test for survivable space. The computer simulation computed the force applied to the roof during the ECE R.66 rollover test, and during other scenarios such as sliding into fixed objects. The key findings for roof forces and window retention are discussed below.

The numerical analysis of a motorcoach rollover showed that passenger occupants would contact the window glazing before the bus is completely on its side. The Transport Canada study also established the basis of a dynamic test procedure that can be used in testing advance glazing materials and bonding techniques to evaluate their effectiveness for prevention of ejection.

Roof Crush Forces

The ECE R.66 numerical analysis determined the average force applied to the roof of a 44 ft. Prevost bus with an unloaded weight of 34,150 lbs during the rollover test would be 258,424 lbs upward and lateral loading with an applied vector angle of 29 degrees relative to the bus longitudinal-transverse plane. It was determined that the average force distribution along the top corner of the bus was approximately 490 lbs/in along the length of the bus. No test procedure was established.

Window Retention

The numerical analysis of a motorcoach rollover determined that the impact velocity of occupants striking the glazing was as much as 20 ft/s. The dummy seated on the far side fell and struck the glazing first with its head followed closely by its torso/shoulder. The torso/shoulder produced the largest loading on the glazing. Numerical analysis using the US_SID (50th percentile adult male) dummy as a model determined that the peak torso

[15] Motor Coach Glazing Retention Test Development for Occupant Impact During a Rollover, August 2006, Docket No. NHTSA-2002-11876-15.

loading was approximately 2,400 lbs with an overall duration of 0.060 seconds. The average torso impact force was 1457 lbs.

The program also looked at indirect loading to the glazing from incidents where the bus runs off the road and its front bumper strikes an embankment, yaws and then rolls over. The numerical analysis determined that passengers near the front of the bus struck the glazing with about the same loading as predicted by the ECE R.66 rollover simulation. It also determined that approximately 0.28 in (7 mm) of displacement around the window perimeter can be expected in this loading condition, and that glazing material would not be likely to break solely from torsional (twist) loading of the bus. Passengers seated in the rear of the bus would strike the roof instead of the glazing material, and would do so later in the sequence of events.

Rather than using the CMVSS/FMVSS[16] No. 217 quasi-static head form test of glazing retention strength, a dynamic impact test device was built that represents the torso of the US_SID test dummy because it more closely replicated the loadings predicted by the numerical simulations. Several drop tests with the US_SID test dummy were performed and compared with a newly built impact test device to validate that the test device suitably represented the force loading predicted by the numerical simulations. The new impact test device consisted of a guided piston and a platform structure that held a piston with guides along with an accumulator tank used for powering the guided piston, Figure 1. A test procedure using the new dynamic impact test device was developed for testing side windows on a motorcoach for retention strength. Subsequently, only one test was performed in a test fixture that represented the side window structure of a motorcoach with glazing material that was bonded at the top and the bottom. No testing was done to determine the variability of the test procedure.

The study concluded that additional testing was needed with the different glazing configurations, such as bonded completely around the perimeter of the glazing, and with different types of glazing materials such as laminated glass and polycarbonates. Also, no testing was done to establish a baseline for the motorcoach fleet. The dynamic test procedure appears to provide a realistic impact condition for window glazing in buses. However, considerably more effort is needed to establish fleet baseline performance, potential improvements for window retention purposes, effects on emergency egress, and cost/benefit potential.

[16] CMVSS – Canadian Motor Vehicle Safety Standard; FMVSS – Federal Motor Vehicle Safety Standard

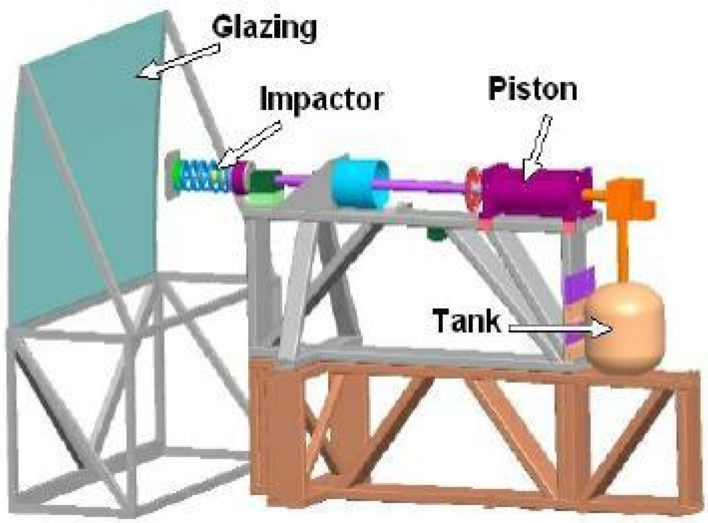

Figure 6: Impact Test Device for Window Retention (Transport Canada Study).

II. Priority Strategies

Various potential prevention, mitigation, and evacuation approaches were considered in developing this report. A number of considerations were weighed in determining the priorities. These considerations for each potential approach included:

- Size of target injury population and potential safety benefits that might be realized
- Likelihood that the effort would lead to the desired and successful conclusion
- Resources and time needed to carryout the research
- NTSB "Most Wanted" listing
- Anticipated cost of implementing the ensuing requirements into the motorcoach fleet

Based on this assessment, the work presented in this section was determined to be priorities that the agency should pursue.

A. Mitigation

The following sections detail priority crash mitigation approaches for improving motorcoach occupant protection.

1. Roof Strength

The NTSB has designated the improvement of roof strength in motorcoaches as one of its "Most Wanted" safety recommendations. Specifically, the NTSB recommends developing performance standards for motorcoach roof strength that provide maximum survival space for all seating positions.[17] Furthermore, roof deformation may affect the structural integrity surrounding the windows, and consequently reduce their effectiveness in preventing occupant ejection.

FMVSS No. 220, "School bus rollover protection," is a roof crush test for school buses that may be adapted for motorcoaches. The performance requirement specifies a quasi-static roof crush test with a horizontal platen applied to the roof at a force equal to 1 ½ times the unloaded vehicle weight. The downward movement of the platen is not allowed to exceed 130 mm, and each emergency exit provided in accordance with FMVSS No. 217 (except for roof exits) is to remain capable of being opened under a specified force.

Alternatively, the test procedure specified by ECE Regulation 66 (ECE R.66) rollover test places the motorcoach on a level surface 800 mm (31.5 inches) above a flat surface, and the motorcoach is tipped over on its side to test for survivable space.

PLANNED APPROACH: An approach for adopting a roof crush requirement for motorcoaches involves the evaluation of two existing roof crush test procedures: FMVSS No. 220 and ECE R.66. A determination will be made to determine which is more stringent or applicable to motorcoaches and what practical countermeasures could be employed.

The following tasks will be required:

1. Conduct a survey of the current motorcoach fleet to determine the range of roof characteristics (such as design, material, pillars, shape, etc.) of existing motorcoach roofs. [2007][18]
2. Based on the fleet survey, select two motorcoach models that "bracket" the fleet in terms of roof characteristics judged to be most and least likely to sustain loading and retain occupant survival space. [2007]
3. Conduct baseline testing using both the FMVSS No. 220 and ECE R.66 test procedures. [2007]
4. Based on the above test results, determine the relative stringency and practicality of the ECE R.66 and FMVSS No. 220 requirements for motorcoaches. [2008]
5. From above testing and analyses, determine feasibility of proceeding with establishment of a roof crush performance requirement for motorcoaches. [2008]

2. Seat Belts

Seat belts are another approach for potential improved motorcoach occupant protection in crashes. Installing seat belts would be the most direct method of retaining passengers within the seating compartment. Many of the fatal motorcoach crashes had fairly high accelerations where advanced glazing material and bonding may not necessarily have

[17] See NTSB recommendation H-99-50.
[18] Dates in brackets denote projected schedules.

withstood the high accelerations. Seat belts could also potentially provide protection in multiple crash modes, including rollover, and prevent ejection.

Both Australia and Europe require seat belts on motorcoaches. Australian Design Rule (ADR) 68 has required lap and shoulder belts since 1994. In Europe, ECE R.80 Amendment 1 has required a lap belt or a lap/shoulder belt since 1998. However, the performance requirements between ADR 68 and ECE 80 differ significantly and we do not have any information to indicate which, if either, might be more appropriate or effective.

The major differences between ADR 68 and ECE 80 involve the crash pulse and loading scenarios; however, the basic set-up of each dynamic requirement is similar. Table 1 is a summary of the specifications from each regulation. The values for velocity change and peak acceleration show that ADR 68 imparts a more severe crash than ECE 80 when considering the strength of the seat and structure. Table 2 compares dummy injury criteria for the two standards.

Table 1. Comparison of ECE and ADR for Bus Seat Belt Regulation.

	ADR 68	**ECE 80**
Velocity Change	49 km/h	30-32 km/h
Peak Acceleration	20g 0.05 sec duration	8-12g 0.08-0.15 sec duration
Average Acceleration	Not Specified	6.5-8.5 g

Table 2. Comparison of ECE and ADR for Dummy Injury Criteria.

	ADR 68	**ECE 80**
Head Injury Criterion (HIC)	< 1,000	< 500
Thorax Acceptability Criterion (ThAC)[19]	< 60 g	< 30 g
Femur Acceptability Criterion (FAC)[20]	< 10 kN	< 10 kN at any time < 8 kN for periods > 20 ms
Sternum Compression	< 76 mm	Not Specified

PLANNED APPROACH: While both Europe and Australia currently have such requirements for seat belts on motorcoaches, they differ. The fundamental information that would be necessary to establish adequate performance requirements for seat belts on motorcoaches does not exist. For example, the crash forces transmitted to the occupant compartment that seat and/or belt anchors would need to sustain are unknown. An approach for applying seat belts to motorcoaches will require the following tasks:

[19] This criterion is determined via the absolute value of the acceleration expressed in *g's* and the acceleration period, expressed in *ms*.
[20] This criterion is determined by the compression load expressed in kN, transmitted axially on each femur of the manikin and measured using the duration of the compression load, expressed in ms.

1. Procure a recent vintage motorcoach and conduct a frontal barrier crash test with instrumented dummies aboard. [2007]
2. Using the crash pulse information obtained from the crash test, conduct sled testing under various conditions to determine the level of occupant protection afforded by each and the forces transmitted to the belt and seat anchors. The sled test conditions would include unbelted, lap belted, and lap/shoulder belted occupants using current North American motorcoach seats as well as European and/or Australian designs. [2007]
3. With this information, develop FMVSS No. 210 type performance requirements for the seat belt assembly and seat anchorages. [2008]

3. Flammability

Presently, fire protection safety is afforded to motorcoach occupants primarily through the requirements and test procedures specified in FMVSS No. 302, "Flammability of interior materials." The standard was established in 1972 (with minor modifications in 1975) and applies to passenger cars, multipurpose passenger vehicles, trucks, and buses. The purpose of the standard is to establish burn resistance requirements for materials used in the occupant compartments of motor vehicles and focuses on reducing deaths and injuries to motor vehicle occupants caused by vehicle fires originating in the interior of the vehicle from sources such as matches and cigarettes. The standard involves a test procedure that measures the horizontal burn rate (the distance a fire is allowed to travel in a given amount of time) of a tested material. The existing standard does not address fires that originate outside the passenger compartment similar to that of the Wilmer, Texas incident.

In addition to flammability of the interior components, the Wilmer, Texas, incident illustrates that it may be worthwhile to examine the flammability of exterior components. While fire mitigation for some components such as the tires may not be practicable, it is reasonable to ensure that any fires which do happen to initiate in the engine compartment or other external locations do not propagate too rapidly into the occupant compartment.

Potentially applicable flammability regulations currently used by other government agencies and the international regulatory authorities include:

- Economic Commission of Europe (ECE) Standard No. 118, Uniform Technical Prescriptions Concerning the Burning Behavior of Materials Used in the Interior Construction of Certain Categories of Motor Vehicles
- Federal Aviation Administration (FAA) Standard No. 49 CFR 25.853 Airworthiness Standard, Flammability and Smoke Emission Tests
- Federal Railway Administration (FRA) Standard No. 49 CFR 238.103 Fire Safety, Flammability and Smoke Emission Tests
- Federal Transit Authority (FTA), Recommendations for Testing the Flammability and Smoke Emission Characteristics of Transit Bus and Van and Rail Transit Vehicle Materials

Other standards, such as the American Society for Testing and Materials (ASTM) Standard E162-06, Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, may also be applicable for consideration.

PLANNED APPROACH: Evaluation of existing fire protection tests and standards will be initiated to assess their relevance to fire and smoke emissions that originate from within and outside the vehicle cabin in motorcoaches and other vehicles applicable to FMVSS No. 302. Several candidate tests or standards will then be selected for testing various vehicle interior compartment materials. The following tasks will be required:

1. Review relevant studies that examine the cause of fires in motorcoaches. Based on the results of the studies, determine best approaches to prevent or mitigate the fire to maximize evacuation time for the bus passengers. [2007]
2. Identify existing flammability standards and test procedures and select which would be most appropriate and/or applicable to motorcoach interior and exterior components. [2007]
3. Select materials both from the exterior of the motorcoach and within the compartment to test for their flammability. Selection would include both those materials currently found on the interior and exterior of motorcoaches, as well as flame retardant materials. [2007]
4. Conduct comparative testing on the selected materials using test procedures identified in Step #1, including baseline testing with the FMVSS No. 302 procedures. [2008]
5. Determine the performance with the various materials relative to established requirements of the respective procedures, and assess the need to adopt more stringent flammability requirements for both interior and external motorcoach components. The assessment would need to consider not only the burn rates, but also the toxicity of current and any flame retardant materials. [2009]

B. Evacuation

1. Emergency Egress

Emergency egress requirements for motorcoaches are established in FMVSS No. 217. The number and type of emergency exits on buses (i.e., motorcoaches) have not changed since inception of the standard, and appear to have been adopted from what was the Interstate Commerce Commission's Motor Carrier Safety Regulations. The number of emergency exits is based on the seating capacity of the motorcoach. FMVSS No. 217 requires 432 square centimeters of emergency exit area per designated seating position, and that 40 percent of the exit area must be on each side of the motorcoach. Motorcoaches typically have 3 to 4 large emergency exit windows on each side and a roof exit. For any one emergency exit, the maximum amount of emergency exit area credit cannot exceed 3,458 square centimeters. This requirement ensures that manufacturers provide multiple emergency exits instead of just one large emergency exit on each side of the bus. The standard requires a rear exit but permits the installation of roof exits in cases where rear exits are not feasible. Motorcoaches generally have roof exits because they have rear-mounted engines.

FMVSS No. 217 also specifies the force with which emergency release mechanisms and emergency exits must operate. While the ease of opening the window in an emergency must be balanced against need to keep it closed to prevent ejection, NTSB Safety Recommendation H-99-9 noted concerns with easily opening and keeping open the emergency exit, particularly when the motorcoach may be in a position that is not fully upright.

E.C.E Regulation No. 36, "Uniform Provisions Concerning the Approval of Large Passenger Vehicles with Regard to their General Construction" is the regulation that governs emergency egress for large buses built for Europe, Australia and Japan. It requires approximately the same number of exits as U.S. requirements, but differs because it specifies design requirements for emergency exits. ECE R.36 requires two roof exits in buses with a seating capacity of 50 or more. There are no force requirements specified for operation of the emergency exits. It specifies that side window emergency exits be made of readily-breakable safety glass. This provision precludes using panes of laminated glass or of plastic materials. Side window emergency exits are of a "breakaway" type that requires a tool such as a small hammer to break. The standard requires two doors, one of which must be a service door. The second door is located on the right side, near the middle, and is typically a service door with a steep incline on the steps leading to the center aisle of the bus.

There are no studies to indicate whether the ECE R.36 or the FMVSS No. 217 requirements provide a more effective and balanced approach to emergency egress and ejection prevention.

PLANNED APPROACH: Research will be performed to examine the type, number and required force to open emergency exits. The following tasks will be required:

1. Identify studies from other modes (e.g., FRA & FAA) and other countries (i.e., Europe) that may be applicable to bus emergency egress requirements, e.g., egress times, interior design (door, latch, hinges, signage), force levels for opening emergency exits, passenger response to egress designs, and any experimental and modeling efforts to study passenger responses during emergency egress. [2007]
2. Determine if any of the above could be directly applicable to motorcoaches.
3. If necessary, conduct human evacuation simulations of different emergency exit scenarios (including motorcoach positioning, secondary exit door as in Europe, aircraft exits, etc.) and determine their effectiveness in reducing evacuation times. [2008-2009]
4. If necessary, conduct human factor testing and analysis to develop an improved minimum strength requirement to open emergency exits. The analysis would include consideration for elderly occupants, while balancing the need for maintaining containment requirements. Determine the effectiveness of the procedure on improving evacuation. [2008-2009]
5. Compile results of Tasks 3 and 4 to determine the feasibility and effectiveness of these approaches [2010]

2. Signage

Emergency exits in buses are required to have the designation "Emergency Exit" followed by operating instructions describing each motion necessary to unlatch and open the exit, located within 6 inches of the release mechanism. The label must be visible, when the source of light is the normal nighttime illumination of the bus interior, to occupants having corrected visual acuity of 20/40 (Snellen ratio) seated in the adjacent seat, seated in the seat directly adjoining the adjacent seat, and standing in the aisle location that is closest to that adjacent seat. Emergency exit signage in school buses, trains, airplanes and buildings have the emergency exit signage at the top of the exit where it can readily seen. One consideration for motorcoaches would be to explore the feasibility and desirability of having signage consistent with other public transportation systems.

PLANNED APPROACH: A review of existing exit signage requirements will be reviewed to determine potential application to motorcoaches. The following tasks will be required:

1. Review FRA, FAA, and school bus signage requirements, as well as agency regulatory review findings to determine the potential suitability and applicability for motorcoaches. [2007]
2. Identify any unique circumstances in motorcoaches that might make incorporation problematic. [2007]

3. Illumination

Current bus requirements specify that the emergency exit markings shall be legible to occupants standing in the aisle location nearest to the emergency exit when the source of light is the normal nighttime illumination of the bus interior . Darkness has been found to be a relevant field condition in bus and motorcoach crashes. A review of FARS 2001-2005 data for buses (other than school buses) revealed that 28 out of 76 fatal crashes occurred with the light condition listed as dark. During this same time period, there were 23 fatal motorcoach crashes with 11 occurring in darkness and 2 occurring after dark but with other artificially lighted (e.g., streetlight) conditions. Therefore, illumination of emergency exit signage could have the potential to improve the time to locate emergency exits for nighttime crash survivors and reduce evacuation time.

Two potential strategies for improving nighttime illumination of emergency exit signage would be photo luminescent signage, and a backup electrical power source for illumination that is independent of the bus's electrical power system.

PLANNED APPROACH: The following approach will be pursued:

1. Review illumination requirements established by FRA and FAA. Review any relevant studies used to develop those standards and any subsequent studies on their effectiveness. [2007]
2. Determine if there are any unique aspects to trains or planes that would make those requirements inappropriate for motorcoaches. [2007]

Upon completion of the various efforts described in this section, the agency will determine what regulatory approach might be most appropriate to improve motorcoach safety on any or all of the priorities described above.

III. Other

This section of the report describes efforts that for various reasons were not given priority to pursue. However, in the prevention area the agency has a number of efforts underway for heavy truck applications that could be applicable to motorcoaches in the future.

A. Prevention

Preventing crashes and fires before they occur is a major component of any comprehensive vehicle safety program, including motorcoach safety. Many of these prevention strategies would rely upon emerging advanced, active safety (i.e., crash avoidance) technologies that are under development. While these technologies may be appropriate for FMVSS development in the future, they are not yet ready for such applications and the immediate focus for most expediently improving motorcoach safety needs to be on those areas listed in Section II.

NHTSA recently issued a final rule for Electronic Stability Control (ESC) in the light vehicle fleet[21]. ESC reduces yaw instability and consequential rollover due to loss of control. Heavy vehicle rollover dynamics differ considerably from light vehicles because their instability about the longitudinal (roll) axis is considerably greater than for light vehicles. Roll Stability Control (RSC) detects and controls stability about the longitudinal axis and potential resulting rollover. Thus for heavy vehicles, ESC/RSC systems improve both yaw and roll stability control in reducing rollover crashes. Research and development is currently being conducted by the agency to understand how these systems work for heavy trucks, what safety benefits can be achieved, and to develop objective performance tests to evaluate these systems. This work is presently focused mainly on tractor trailer combination vehicles, but will include single-unit trucks and buses as well.

A Lane Departure Warning (LDW) system is a mechanism designed to warn a driver when his or her vehicle begins to move out of its lane (unless a turn signal is on in that direction) on freeways and arterial roads. LDW systems have been available for use by

[21] 72 Federal Register 17235, April 6, 2007.

commercial trucking fleets for several years. This technology is just beginning to emerge in light passenger vehicles. However, there is presently no research demonstrating the best method to alert the driver. More research is needed to determine the human factors considerations for private, commercial vehicle and motorcoach applications before it can be evaluated for incorporation into a FMVSS[22].

As with LDW, Forward Collision Warning (FCW) and Adaptive Cruise Control (ACC) systems have been available for use by commercial fleets for several years. However, Greyhound removed FCW from their fleet a few years ago due to operational difficulties with inadvertent and/or misleading warnings. NHTSA recently completed a large scale field operational test to assess the effectiveness of Adaptive Cruise Control (ACC), Forward Collision Warning (FCW) and electronically controlled air disc brake systems for heavy trucks[23]. The field study provided preliminary indications that crash reduction of about 28% would result from this suite of technologies, with about 21% of this reduction due to the FCW system. Analysis of real-world crashes are underway to see if these preliminary findings would hold true and translate to the broader crash population.[24] Potential applicability to motorcoaches will be considered in conjunction with requirements for heavy truck applications.

Sources of motorcoach fires have included the wheel/brake/bearing/axle/tire (as in the Wilmer, Texas fire in 2006), engine compartment, and electrical systems[25]. The agency is aware of various sensors and methods either in existence or being developed in the private sector that would detect conditions indicative of a potential fire, or provide fire suppression. The agency will monitor the development of these technologies, as well as any field experiences, to determine their practicability for future standards development. However, the agency has decided that attention to the priority strategies identified in the previous section is where the focus needs to be directed to have the most immediate impact on motorcoach safety.

B. Mitigation

Over the past ten years, 55 passenger fatalities in motorcoach crashes have involved the passenger being ejected from the motorcoach. Most of these fatalities were from the passengers being ejected through a motorcoach window. Preliminary work, under a joint research program with Transport Canada, estimated the forces applied to the window structure during rollover events and impacts to the window glazing[26]. This program also developed a test procedure for evaluating advance glazing materials and bonding

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[22] FMCSA is currently performing a study to determine the naturalistic causes of drowsy drivers and develop a multi-sensor approach to detecting drowsiness to get a reliable method of detection and warning for all drivers.

[23] "Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test," NHTSA, January 2007

[24] Both naturalistic and crash reconstruction data from other studies are being used to assess the rear-end crash and near crash events recorded to determine how many of these safety critical events might have been prevented or mitigated if collision warning technology would have been present in the vehicle.

[25] FMCSA is performing a study to determine the causes, frequency and severity of motorcoach fires.

[26] Idem

techniques in the prevention of ejection. The test procedure was designed to replicate the loading of an occupant's upper torso during typical ejection situations.

While the joint study that was completed in 2006 provided important first steps necessary to develop a test procedure for a performance requirement, considerably more effort would be needed to establish fleet baseline performance, develop potential improvements for glazing and window retention, determine effects on emergency egress, and establish cost/benefit potential. Also, review of motorcoach crashes has shown that many sustain significant structural deformation in the window frame area, thus compromising the capability of the window to prevent an occupant ejection. The roof strength strategy included in Section II of this report would likely provide improved structural integrity for the window glazing, and the agency believes that pursing the seat belt and roof strength approaches has greater potential for providing improved motorcoach occupant protection than continuing only the glazing/window retention strategy.

IV. Electronic Data Recorders

The following two NTSB safety recommendations do not specifically relate to changes in motorcoach safety performance requirements that would have direct or quantifiable safety benefits for motorcoach occupants. However, they could provide the potential to obtain valuable information that might aid future motorcoach crash investigations and improve the data to support future occupant safety improvements.

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 a minimum, lateral acceleration, longitudinal acceleration, virtual 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 development 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 electric 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 immersion survivability, impact shock survivability, fire survivability,

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

PLANNED APPROACH: The following approach is being pursued:

The agency has recently established requirements for voluntarily installed Event Data Recorders (EDRs) in light passenger vehicles. However, the crash characteristics and relevant measurements that would be necessary for motorcoaches would be considerably different. For the past several years, NHTSA has been working with the Society of Automotive Engineers (SAE) Truck and Bus Committee in the development of SAE Recommended Practice J2728, "Heavy Vehicle Event Data Recorder (HVEDR) – Base Standard." This standard is being developed to define specifications and functional requirements for HVEDRs for the reliable and accurate recording of the crash parameters that are relevant to heavy trucks. Upon completion of J2728, consideration of a requirement for HVEDRs installation into motorcoaches would then be appropriate.

V. Summary

The various potential prevention, mitigation, and evacuation approaches presented in this report were evaluated to determine priorities for improving motorcoach safety. A number of considerations were weighed in determining the priorities. These considerations for each potential approach included:

- Size of target injury population and potential safety benefits that might be realized
- Likelihood that the effort would lead to the desired and successful conclusion
- Resources and time needed to carryout the research
- NTSB "Most Wanted" listing
- Anticipated cost of implementing the ensuing requirements into the motorcoach fleet

Based on this assessment, the priority efforts identified are the following efforts:

Mitigation:

- Roof Strength
- Seat belts
- Flammability

Evacuation:

- Emergency Egress
- Signage
- Illumination

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