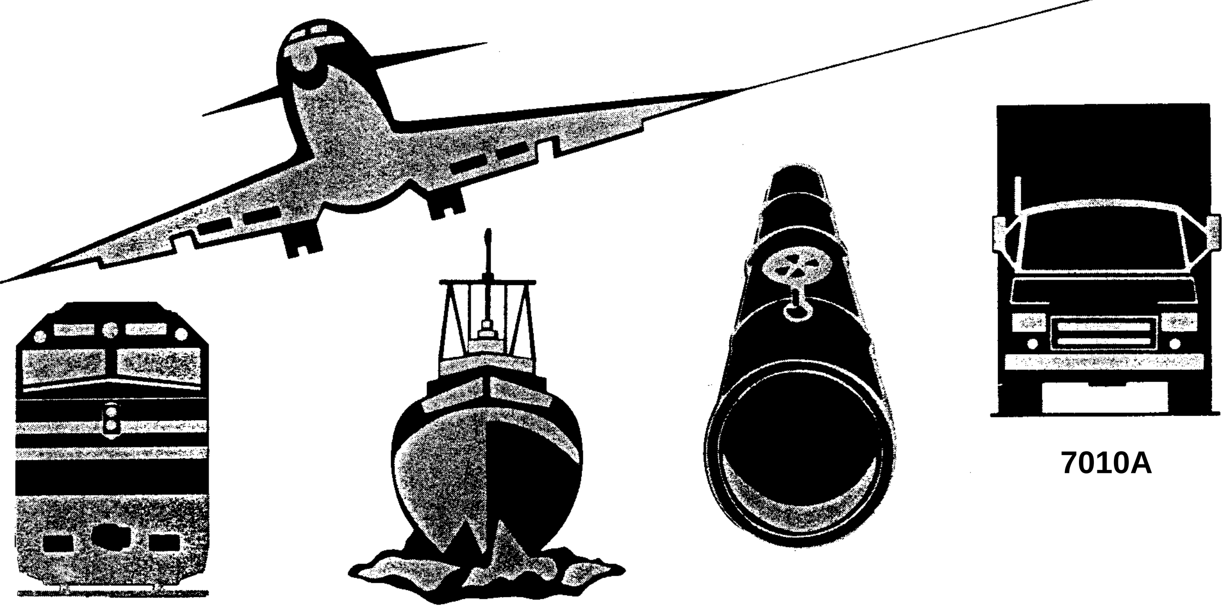
PB98-917006
NTSB/SIR-99/04

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HIGHWAY SPECIAL INVESTIGATION REPORT

BUS CRASHWORTHINESS ISSUES



7010A

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

Abstract: School bus and motorcoach travel are two of the safest forms of transportation in the United States. Each year, on average, nine school bus passengers and four motorcoach passengers are fatally injured in bus crashes, according to National Highway Traffic Safety Administration (NHTSA) and motorcoach industry statistics. In comparison, NHTSA statistics show that in 1998 over 41,000 people were fatally injured in highway crashes. Although much has been done to improve the safety of school buses and motorcoaches over the years, the safe transportation of bus passengers, especially students and senior citizens, continues to be a national safety priority. Children and seniors are predicted to be the fastest growing segments of our society, and these groups are the primary users of bus transportation.

The National Transportation Safety Board initiated this special investigation to determine whether additional measures should be taken to better protect bus occupants. It examines school bus and motorcoach crashworthiness issues through the analysis of 6 school bus and 40 bus accidents and through information gathered at the Safety Board's August 12, 1998, public hearing. This special investigation addresses the following crucial safety issues:

- Effectiveness of current school bus occupant protection systems;
- Effectiveness of Federal motorcoach bus crashworthiness standards and occupant protection systems;
- Discrepancies among different Federal bus definitions;
- Deficiencies in the National Highway Traffic Safety Administration's Fatality Analysis Reporting Systems bus ejection data; and
- Lack of school bus injury data.

As a result of this special investigation, the Safety Board makes recommendations to the U.S. Department of Transportation, the National Highway Traffic Safety Administration, the National Association of Governors' Highway Safety Representatives, and the bus manufacturers.

Highway Special Investigation Report

Bus Crashworthiness Issues

NTSB/SIR-99/04
PB99-917006
Notation 7010A
Adopted: September 21, 1999

National Transportation Safety Board
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Washington, D.C. 20594

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Introduction

School bus and motorcoach travel are two of the safest forms of transportation in the United States. Each year, on average, nine school bus passengers and four motorcoach passengers are fatally injured in bus crashes, according to National Highway Traffic Safety Administration (NHTSA) and motorcoach industry statistics. In comparison, NHTSA statistics show that in 1998 over 41,000 people were fatally injured in highway crashes. Although much has been done to improve the safety of school buses and motorcoaches over the years, the safe transportation of bus passengers, especially students and senior citizens, continues to be a national safety priority. Children and seniors are predicted to be the fastest growing segments of our society, and these groups are the primary users of bus transportation. Therefore, the National Transportation Safety Board initiated this special investigation to determine whether additional measures should be taken to better protect bus occupants.

To address crucial safety questions on bus safety, this special investigation examines school bus and motorcoach crashworthiness issues through the analysis of 6 school bus and 40 bus accidents and through information gathered at the Safety Board's August 12, 1998, public hearing. (See appendix A.) This report also evaluates the Federal Motor Vehicle Safety Standards (FMVSS) that govern the design of school buses and motorcoaches to determine the effectiveness of these standards and to determine whether further occupant protection measures are needed. Also included here are the results of computer simulations performed to evaluate the safety levels afforded by passenger crash protection systems not currently required for school buses. Further, the report reviews international perspectives on, and developments in, motorcoach occupant protection. Finally, the report addresses data collection issues that are hampering effective accident study. During the Safety Board's discussion of bus crashworthiness issues, this special investigation identifies the following safety issues:

- Effectiveness of current school bus occupant protection systems;
- Effectiveness of Federal motorcoach bus crashworthiness standards and occupant protection systems;
- Discrepancies among different Federal bus definitions;
- Deficiencies in the National Highway Traffic Safety Administration's Fatality Analysis Reporting Systems bus ejection data; and
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Background

School Bus Occupant Protection

Current large school bus occupant protection is based on a concept called compartmentalization:[1] the seats are strong, closely spaced together, high backed, well padded, and designed to absorb energy during a crash. This concept evolved from both crash testing research and Federal rulemaking by the National Highway Traffic Safety Administration (NHTSA).

In 1967, Dynamic Science and the University of California at Los Angeles[2] conducted three crash tests on prestandard (manufactured before April 1977) large school buses.[3] A variety of dummy types and sizes were used in the tests, as well as a number of different belts, restraint bars, and air bags. The researchers concluded that the high seatback (28 inches) was the most important safety feature for large school buses, followed by the use of lap/shoulder belts, lap belts, or another form of restraint. The researchers cautioned against the use of lap belts with low seatbacks because of the risk of head injury.

In 1974, after the Safety Board investigated a series of school bus accidents, Congress directed the National Highway Traffic Safety Administration (NHTSA) to establish or upgrade school bus safety standards in eight areas: emergency exits, interior occupant protection, floor strength, seating systems, crashworthiness of the body and frame, vehicle operating systems, windshields and windows, and fuel systems. As a result of this directive, NHTSA, on April 1, 1977, amended or established new motor vehicle safety standards for school buses, including FMVSS 222, *School Bus Passenger Seating and Crash Protection*. This standard improved the crash protection provided by school buses through compartmentalization. However, the standard did not require the installation of seat belts. And, even after the 1977 standards were implemented, researchers and safety advocates continued to examine and debate the effectiveness of seat belts in school buses.

In 1984, Transport Canada[4] conducted three poststandard (manufactured after April 1977) school bus crash tests. Each vehicle (two small school buses and one large

[1] In school buses, compartmentalization is used to protect passengers from crash impacts. This is accomplished by having the seats closely spaced together, with the seat cushions and high seatbacks covered in an energy-absorbing material. The entire seat structure is designed to absorb energy and to deform to dissipate the energy of the crash away from the passenger and into the surrounding compartment.

[2] Severy, D.M., Brink, H.M., and Baird, J., *School Bus Passenger Protection*, Society of Automotive Engineers, Institute of Transportation and Traffic Engineering, University of California at Los Angeles, 1967.

[3] A large school bus is defined as one with a gross vehicle weight of more than 10,000 pounds. Before 1977, large school buses were built to the same FMVSS requirements as multipurpose passenger vehicles.

[4] Farr, G.N., *School Bus Safety Study—Volume 1, Traffic Safety Standards and Research*, Crashworthiness Section, Transport Canada, Quebec City, Canada, 1985.

school bus) was subjected to a frontal barrier crash test at approximately 30 mph. The purpose of these tests was to determine the effectiveness of compartmentalization versus seat belts. The results indicated that restrained (lap-belted) dummies experienced higher head accelerations than their unbelted counterparts. The researchers stated that the increased head accelerations resulted from the dummies' heads striking the seatbacks in front such that efficient energy absorption was not possible. The researchers concluded that compartmentalization functions as intended during frontal impacts, providing good protection for occupants seated within the compartment, and that lap belts could potentially increase occupant injuries.

Thomas Built Buses, Inc., performed crash tests on three small school buses in 1985. Thomas Built concluded from these tests that compartmentalization functions as designed in both frontal and side impacts. In addition, Thomas Built found little difference in head and chest injuries between the lap-belted dummies and the unrestrained dummies.

In 1987, the Safety Board conducted a safety study of large school buses.[5] The study included 43 serious school bus crashes investigated by the Safety Board, including frontal impacts, side impacts, and rollovers, many of which were preceded by a collision. The Safety Board concluded that the deaths and serious injuries to the school bus occupants were mainly the result of the occupants being in direct line with the crash forces. The Board also analyzed the beneficial effects lap belts may have had during each crash and concluded that it was unlikely that restraints would have improved the injury outcome. Generally, the Safety Board concluded that lap belts probably would not have affected the total number of deaths in these school bus crashes. Furthermore, the Board concluded that the then-current compartmentalization worked well to protect school bus occupants from injuries in all types of crashes.

Since the 1987 Safety Board study, the debate has increased regarding whether passenger protection, especially in side impact and rollover accidents, can be improved by seat belts on school buses. Recently, the most serious school bus accidents have involved collisions with vehicles of large mass (trucks and trains). In these crashes, some of the passengers that were killed or seriously injured were not seated near the area of impact. Additionally, four States (New York, New Jersey, Louisiana, and Florida) have passed legislation requiring that large school buses be equipped with seat belts. Seat belt advocates argue that lap belts may provide crashworthiness benefits during a collision, and that, at a minimum, equipping large school buses with lap belts provides children with message continuity regarding the safety benefits of seat belts. Conversely, others believe that, because of compartmentalization, no particular safety benefit would be derived from seat belts, and furthermore, they are concerned that lap belts may cause additional injuries to children.

[5] For further information, read *Crashworthiness of Large Poststandard Schoolbuses*, NTSB/SS-87/01, Washington, DC.

Motorcoach Occupant Protection

The occupant protection concerns for motorcoaches are somewhat different than those for school buses. More than 360 million bus passengers travel 28 billion passenger miles annually in North America by motorcoach. Most motorcoaches today are equipped with high-backed passenger seats and have large panoramic windows. Through its investigations, the Safety Board has found that, because motorcoaches are larger in mass and have a lower center of gravity than school buses, they often respond quite differently during collisions. As with school buses, the Board has found that those occupants seated within the direct line of impact are often the most severely injured. However, unlike school buses, the Board has found that fatal injuries in motorcoach accidents are often the result of passenger ejection from the coach. A broader discussion of the history and Safety Board recommendations regarding motorcoach occupant protection appears later in this report.

Public Hearing Information

On August 12, 1998, the Safety Board held a public hearing in Las Vegas, Nevada, on "Bus Crashworthiness and Survivability: International and Domestic Perspectives on Bus Occupant Protection." Testimony on occupant protection and applicable regulations was offered by Government, academic, and industry experts, with witnesses coming from Canada, Europe, Australia, and across the United States. The purpose of the hearing was to explore ways to protect occupants in bus crashes, including bus design and manufacturing regulatory standards, restraints used in other countries, and other types of injury-reducing mechanisms.

The public hearing provided the Safety Board with important information concerning the current status of occupant crash protection on buses around the world, including information about areas where occupant protection can be improved and what types of protection are suitable for passengers on buses.

In the area of school bus safety, the public hearing illuminated concerns of some experts about the injury-producing potential of lap belts when used by children involved in frontal impact collisions. Some witnesses suggested that compartmentalization works better than lap belts in frontal collisions and that, because side collisions are generally not as violent as frontal collisions (except for those occupants seated in the area of intrusion), the issue of seat belts is not critical for side collisions. Results from the 1985 Canadian testing were reiterated at the public hearing. The testing indicated that injuries may be increased by the addition of lap belts on the current school bus seat.

At the public hearing, NHTSA presented its new school transportation research plan "…to develop the next generation of occupant protection for school bus passengers." NHTSA plans to conduct research in three phases: 1) define needed actions; 2) develop testing procedures that best simulate accidents leading to serious injuries; and 3) test and validate new occupant protection systems. The Safety Board is encouraged that NHTSA has completed Phase I and is finalizing its report on that phase. Phase II of the plan has begun with the crash testing of two school buses. One test consisted of a conventional-body large school bus being crashed at 30 mph into a rigid barrier, and the other test consisted of a stationary large transit-style (flat nose) school bus being struck in the side by a 25,000-pound tractor semitrailer traveling at 45 mph. At this time, NHTSA is developing the information gathered in the crash tests for use in investigating potential new occupant protection systems for school bus passengers. The Safety Board is optimistic that this research and more like it will result in occupant protection measures that provide a safer environment for passengers within school buses. NHTSA anticipates completing its research in the fall of 2000.

In the area of motorcoach safety, the public hearing produced information indicating that other countries—the European Union member states and Australia—already have regulations requiring the installation of passenger restraints on motorcoaches.[6] In the European Union, legislation was passed requiring that all motorcoaches manufactured after October 1999 have either a lap belt and energy-absorbing seat or a lap/shoulder belt installed at every passenger position. The Australian restraint regulation was going to be similar to the European Union regulation until a seat was designed with stronger anchorages that incorporated lap/shoulder belts. A restraint regulation with lap/shoulder standards is in effect in Australia for all motorcoaches manufactured since 1994, and, currently, most motorcoaches have the new seat restraint systems.

At the conclusion of the public hearing, the majority of those participating indicated a belief that additional research into bus occupant protection needed to be conducted. The NHTSA testing is a starting point.

[6] The United States and Canada are the only countries that use "yellow school buses" for school transportation. Other countries use small buses and motorcoaches for student transportation. Thus, little useful comparative experience was available from other countries regarding school bus transport.

School Bus Crashworthiness Issues

Overview

Since August 1996, the National Transportation Safety Board has investigated six school bus accidents in which passenger fatalities or serious injuries occurred away from the area of vehicle impact. This represents a departure from the circumstances of the accidents discussed in the Safety Board's 1987 Large School Bus Study,[7] in which intrusion caused all but 2 of the 13 fatalities and caused most of the moderate or greater injuries. In addition, the more recent accidents were unlike the accidents in the 1987 Large School Bus Study. These accidents involved lateral (side) impacts with vehicles of large mass, lateral (side) impacts with vehicles of large mass and rollover, and single-vehicle rollover. The Safety Board still believes that compartmentalization is a very effective means of protecting passengers in school bus accidents. However, because many of the passengers injured in the recent accidents were believed to have been thrown out of their compartments during the accidents and thus were unprotected, the Board believes that other means of occupant protection should be examined. Therefore, the Safety Board initiated this special investigation to determine the potential injury mechanisms involved in the six recent accidents and to evaluate whether currently available occupant protection systems for school buses might have mitigated injury in accidents involving rollover or high lateral forces. Table 1 lists these accidents in the order discussed.

The six accidents examined by the Safety Board occurred from 1996 to 1998 (see table 1). Four of these accidents (Easton, Buffalo, Holmdel, and Monticello) involved side impacts of a large school bus with another large vehicle of equal or greater weight. The Holyoke accident involved a rear impact followed by a rollover of the bus. The Flagstaff accident was a single-vehicle rollover that was not preceded by a collision.

Three of these accidents were simulated by the Safety Board to better understand the dynamics of the vehicles during the collision sequence and also to simulate the occupant kinematics of a representative accident (Holyoke, Holmdel, and Monticello). The Monticello occupant simulation was conducted to determine the possible kinematics of the occupants during this complicated accident scenario in which multiple impacts occurred and also to determine the potential injury producing impacts. The Holyoke simulation was conducted to determine a potential ejection path of the two simulated

[7] For further information, read *Crashworthiness of Large Poststandard Schoolbuses*, NTSB/SS-87/01, Washington, DC. No information from this study, beyond the current applicable Federal Motor Vehicle Safety Standards (FMVSS), will be included in this special investigation. No changes have been made to the passenger protection standards applicable to large school buses since the Safety Board adopted the Large School Bus Study in 1987. Safety improvements have been made in other areas, including an amendment to FMVSS 217 requiring additional emergency exits and the addition of a requirement for wheelchair securements to FMVSS 222. Other changes include modifications to the mirror requirements of FMVSS 111; changes to the body joint strength of FMVSS 221; and the establishment of a new standard, FMVSS 131, requiring stop signal arms. (For more information on FMVSS applicable to school buses, see appendix B.)

Table 1. School bus accidents analyzed

Accident	Date	Fatalities	Injured	Not Injured[1]
Nonsimulated Accidents[2]				
Flagstaff, Arizona (WRH-96-F-H014)	08/14/96	0	31	1
Easton, Maryland (HWY-98-M-H005)	10/31/97	1	25	12
Buffalo, Montana (HWY-98-M-H022)	03/10/98	2	4	0
Simulated Accidents[2]				
Monticello, Minnesota (CRH-97-F-H004)	04/10/97	3	11	0
Holyoke, Colorado (HWY-98-F-H043)	09/01/98	0	11	2
Holmdel, New Jersey (HWY-98-F-H045)	09/18/98	0	7	0
Total		5-Passengers 1-Driver	85-Passengers 4-Drivers	14-Passengers 1-Driver

[1] Includes passengers who may have received minor injuries but were not examined by professional medical personnel.

[2] Nonsimulated accidents were analyzed based on reported vehicle dynamics and injury data. Simulated accidents were analyzed using a variety of computer programs capable of evaluating specific mechanical and biomechanical issues for similar types of accidents. A simulation does not replicate the actual accident.

occupants seated in the rear of the bus on the driver's side. The Holmdel simulation was conducted to determine the possible occupant kinematics during an accident resulting in serious injury to an occupant on the opposite side from the impact. For all three accidents, the effectiveness of compartmentalization was investigated, as well as the potential restraint systems currently available for large school buses.

The remaining three accidents were not simulated for a variety of reasons. The Flagstaff accident involved an extremely complicated rollover where the sequence of events was unclear. Because the vehicle dynamics were not fully understood, occupant kinematics would be difficult to accurately determine, requiring that a number of assumptions be made and, thereby, limiting the conclusions drawn from such a simulation. The Easton accident was not simulated because the vehicle and occupant kinematics were similar to the kinematics of other accidents being simulated. As in the Monticello and the Holmdel accidents, the school bus in the Easton accident was struck by a large truck. In addition, an occupant on the opposite side of the bus from the impact was injured, as in the Holmdel accident. The Buffalo accident involved the collision of a train into the side, rear portion of a large school bus. Two passengers in the rear of the vehicle, one in the area of intrusion and one across from the area of intrusion, were fatally injured while the passengers at the front of the bus, away from the intrusion, sustained only minor or moderate injuries. Consequently, this accident was not simulated because the impact experienced by the bus was too severe to have expected any occupant protection system to reduce the level of injury sustained by the two fatally injured passengers.

Nonsimulated Accidents

The Flagstaff, Easton, and Buffalo accidents resulted in serious injuries or fatalities to passengers seated away from the crash impact area but propelled from their compartments due to the high crash forces experienced during these accidents. These passengers subsequently struck surfaces not designed to absorb crash energy, such as the bus' roof and side walls, sides of seatbacks, or other passengers. Crashworthiness issues specific to these accidents are summarized below.

Flagstaff, Arizona

In this accident, a 72-passenger school bus rolled over after the driver lost control of it. Although no fatalities resulted, five passengers were ejected from the bus. (See figures 1 and 2.) Of the ejected passengers, one was severely injured (AIS-4)[8,9] and four received minor to moderate injuries (AIS-1 and -2). (See seats 1A, 1F, 8A, 9A, and 10A in figure 3.) The lap-belted driver received severe injuries (AIS-4). The passengers on the driver's side received minor to moderate injuries (AIS-1 and -2). The only serious to critical injuries (AIS-3 to -5) occurred to passengers seated on the right-hand side of the bus (seats 1F, 5E, 6F, and 12D), most likely as the result of being propelled out of their compartments and striking surfaces not designed to absorb impact energy. Because only one of five ejected passengers was seriously injured and because the injury levels of passengers located in proximity to each other on the bus differed substantially, it is difficult to determine whether an occupant restraint system would have mitigated or prevented injuries.

Figure 1. Flagstaff school bus postaccident damage

[8] Abbreviated Injury Scale (AIS) refers to the abbreviated injury scale (revised 1990) of the American Association for the Advancement of Automotive Medicine. The AIS classifies injuries as follows: AIS-0=No injury; AIS-1=Minor; AIS-2=Moderate; AIS-3=Serious; AIS-4=Severe; AIS-5=Critical; AIS-6=Unsurvivable; and AIS-9=Unknown.

[9] See last page of this document for a list of all acronyms and abbreviations used in this report.

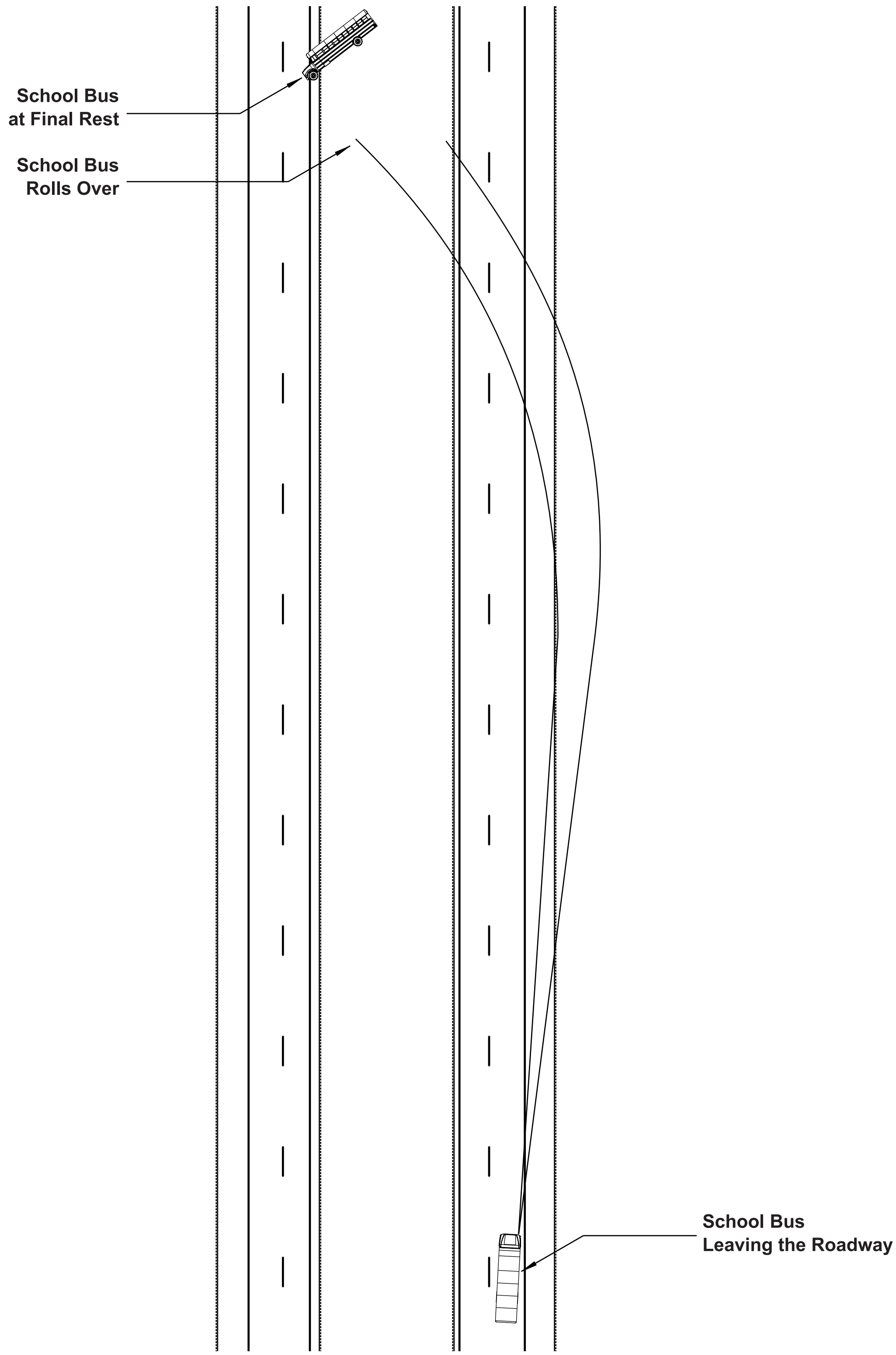

Figure 2. Flagstaff accident scene diagram

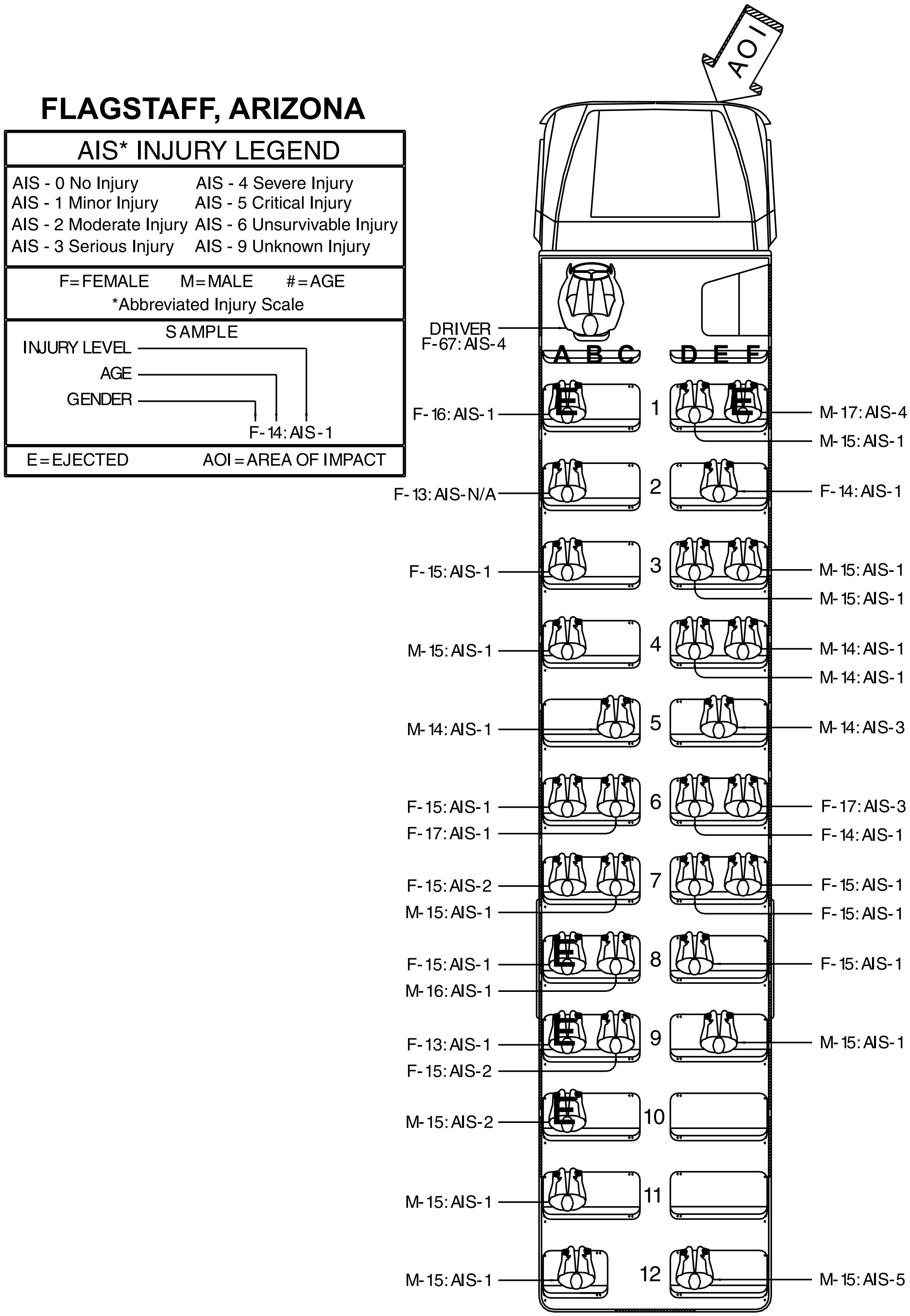

Figure 3. Flagstaff bus seating diagram

Easton, Maryland

In this accident, a 66-passenger school bus was struck at an intersection by a truck pulling an empty semitrailer. The truck cab initially struck the left side of the school bus near the driver's window, causing the bus to rotate in a clockwise direction. The second impact occurred when the right-front corner of the semitrailer swung into the rotating bus, then struck the left side of the school bus near the rear axle. (See figures 4 and 5).

The lap-belted driver was fatally injured as a result of high crash forces in the intrusion area. Three of the four passengers seated in row 1 (figure 6), directly behind the driver, sustained minor injuries. Although these passengers would not have experienced the same level of intrusion as the driver, they would have experienced similar vehicle dynamics. The other passenger in row 1, who was furthest from the impact in seat 1F, experienced serious injuries (AIS-3), most likely sustained from being propelled toward the impact zone. Three of the four most seriously injured passengers (seats 1F, 7F, and 8E) were originally seated on the side of the bus opposite the two impact areas and were likely injured from being propelled from their compartments into the impact area by the high lateral forces experienced during the accident and from striking surfaces not designed to absorb crash energy. Passenger restraints may have reduced passenger injuries by preventing the lateral movement of passengers toward the impact area and by preventing passengers from striking each other. However, because a properly worn lap belt limits the motion of the pelvis relative to the upper body, the restrained passenger's upper body could have been whipped sideways by lateral crash forces.[10] This whipping action may result in high forces being concentrated on the head, possibly causing serious injury. The passengers displaced by the initial impact away from the area of secondary impact (seats 8A, 9A, and 9C in figure 6) may have received worse injuries had they been wearing restraints because of greater exposure to intrusion.

[10] Similar kinematics would be experienced by a passenger who slid out of the shoulder portion of a lap/shoulder belt due to belt orientation and vehicle dynamics.

Figure 4. Easton school bus postaccident damage

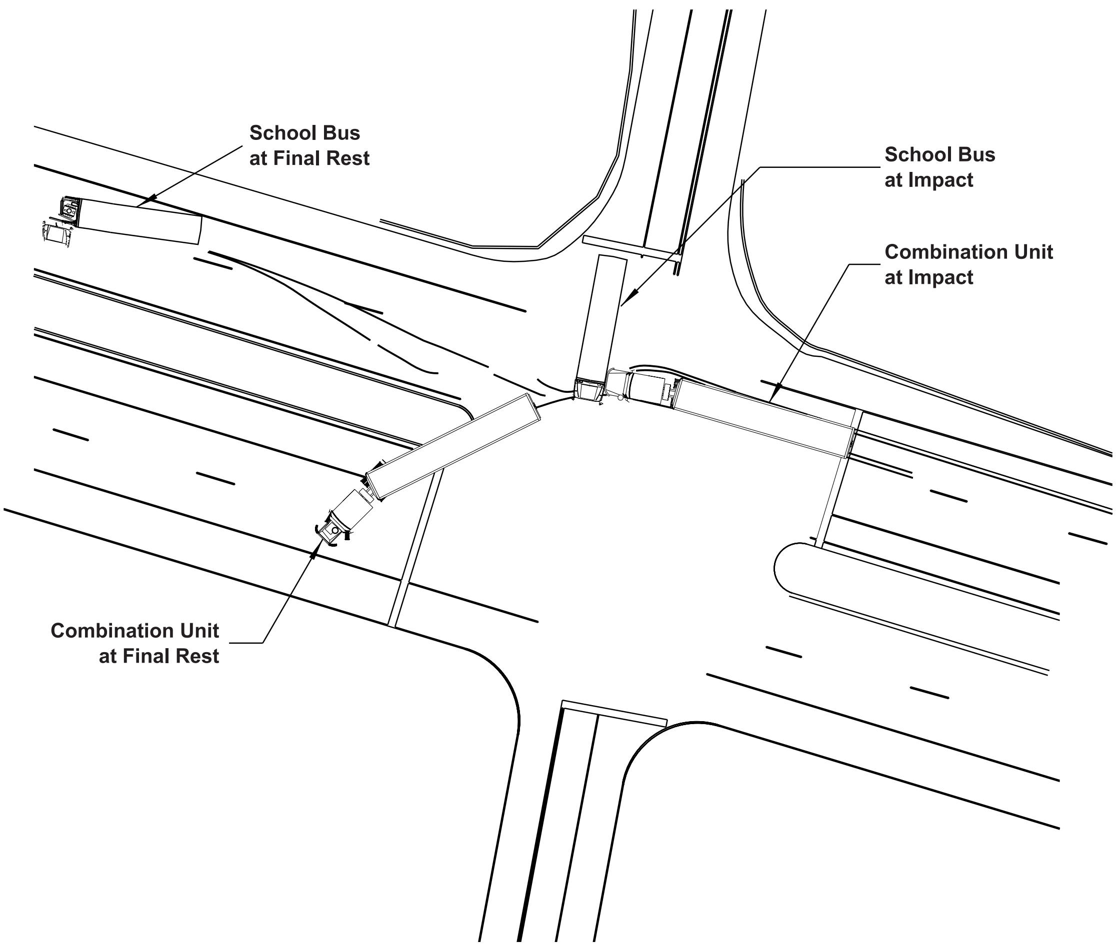

Figure 5. Easton accident scene diagram

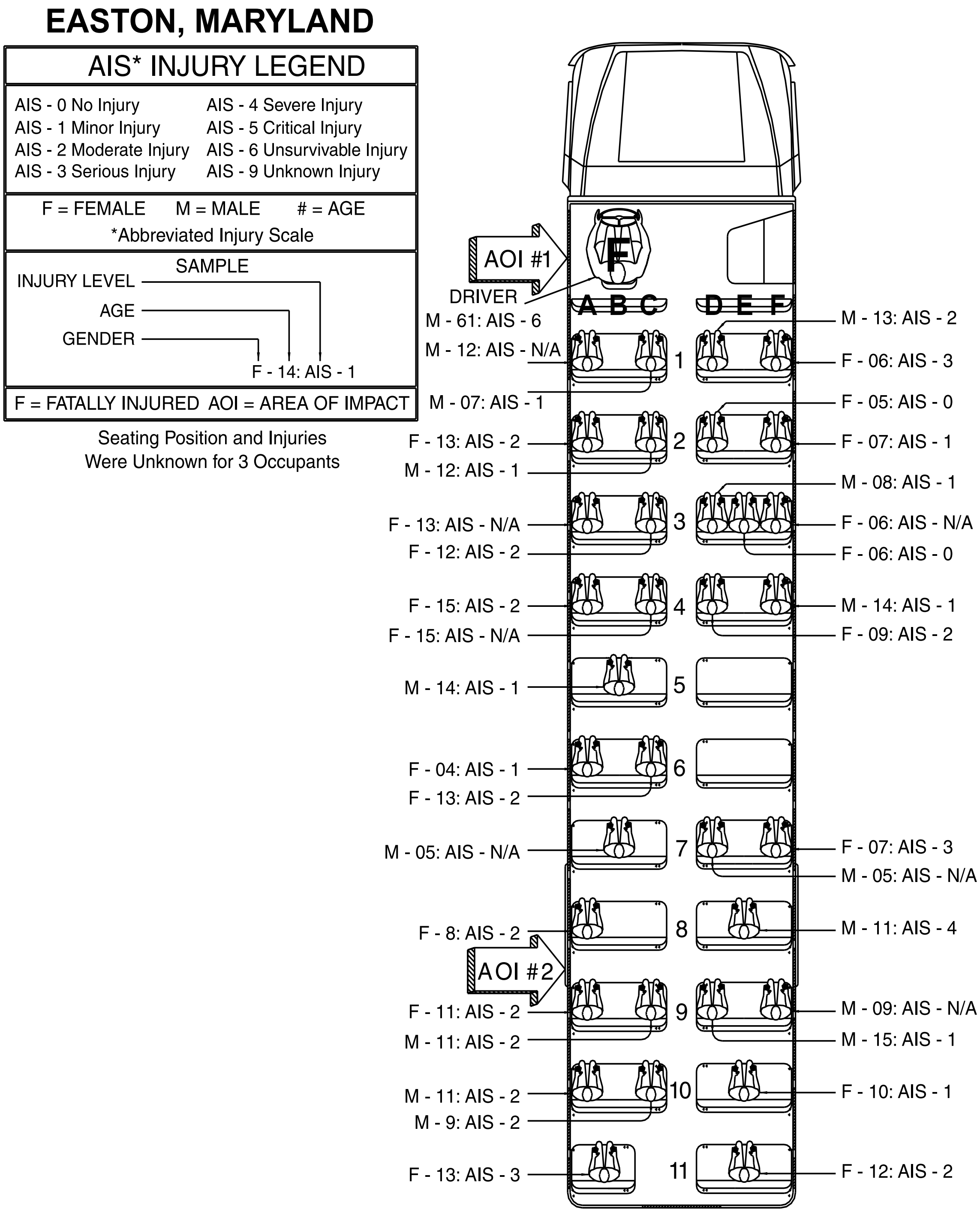

Figure 6. Easton bus seating diagram

Buffalo, Montana

In this accident, a freight train traveling 45 mph struck a school bus between the bus' rear axle and left rear bumper. The impact caused the bus to rotate 180 degrees counterclockwise, and the bus body to separate from its chassis. (See figures 7 and 8.) The passenger in seat 7B was fatally injured from the train's intrusion and resulting crash forces. (See figure 9.) The other fatally injured passenger (seat 7E) was likely thrown into the impact zone during the collision and sustained critical head injuries from the impact forces. Although a restraint system would have reduced the chances of this passenger being propelled into the impact zone, the restraint may not have prevented injuries resulting from the high crash forces due to the severe lateral impact. In addition, had the restraint been a correctly worn lap belt, the passenger's pelvis motion would have been limited relative to the seat, causing his upper body to be whipped sideways, potentially resulting in head injuries similar to those actually received in the accident.[11] The driver and other passengers, who were seated at the front of the bus, did not receive serious injuries.

Figure 7. Buffalo school bus postaccident damage

[11] This may also occur with a lap/shoulder belt, depending upon belt orientation.

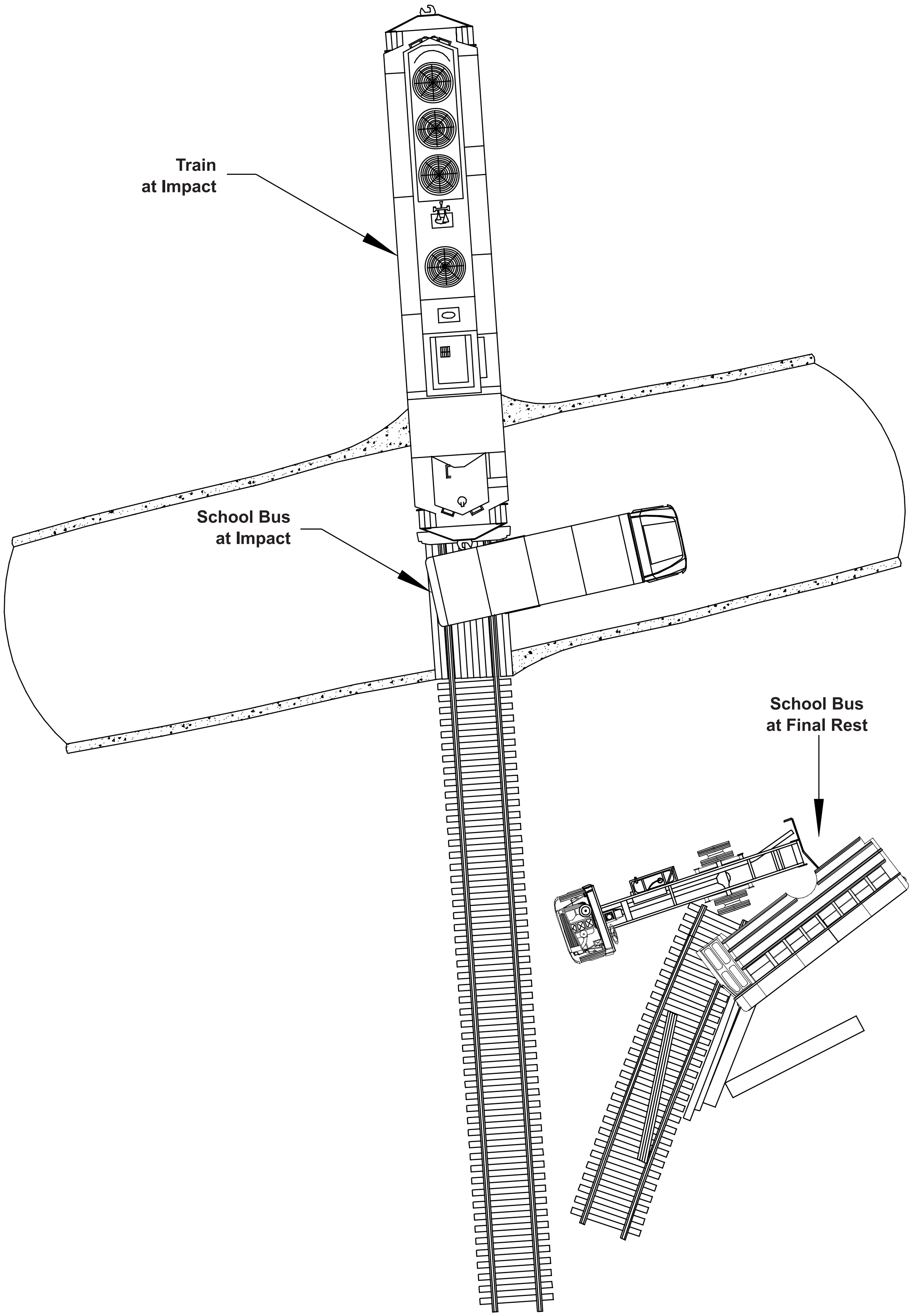

Figure 8. Buffalo accident scene diagram

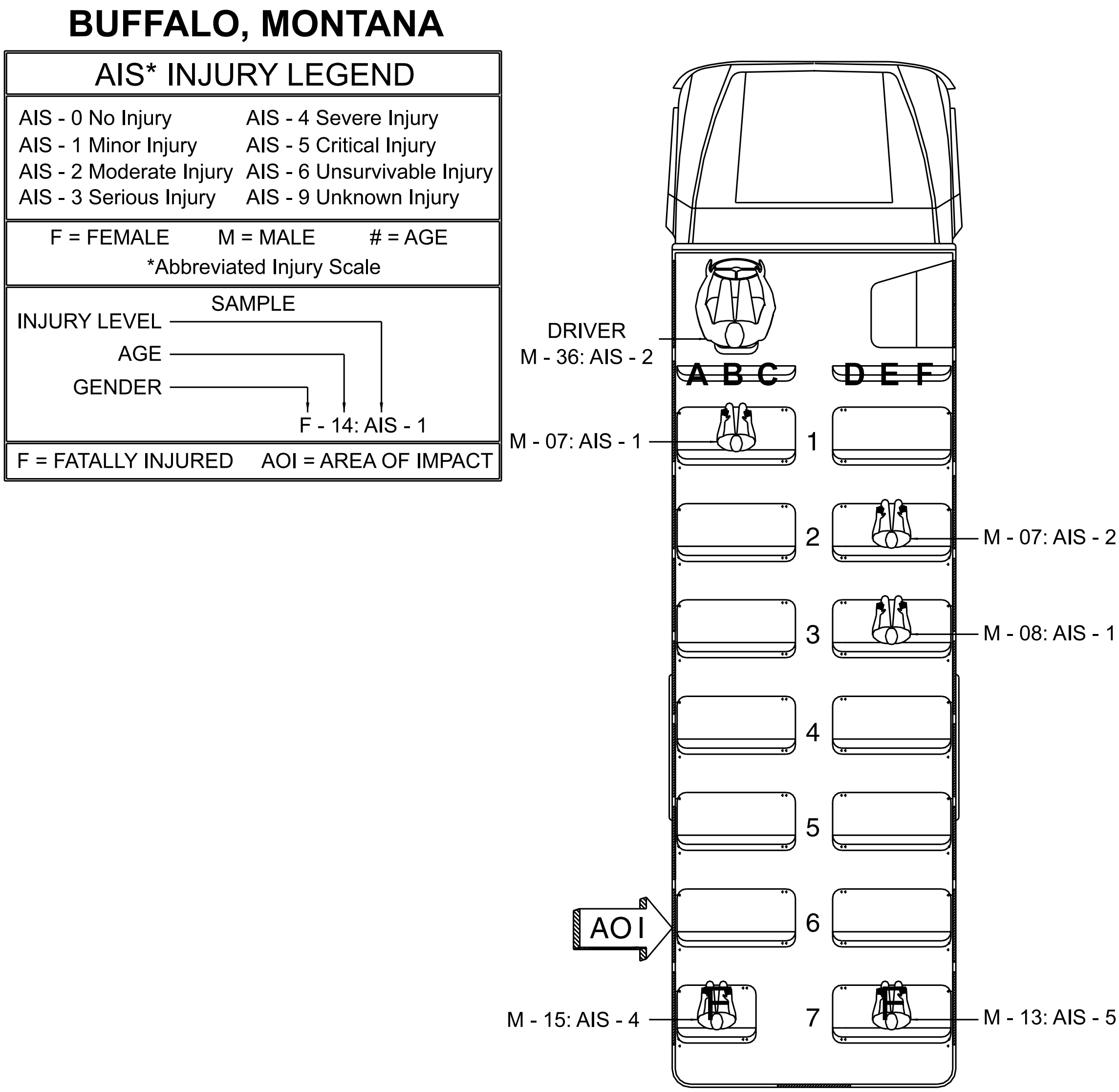

Figure 9. Buffalo bus seating diagram

Simulated Accidents

Methodology

Each simulated accident was evaluated twice: first, to determine the dynamics of the vehicles involved in the collision and second, to evaluate possible occupant kinematics using vehicle dynamic data. Although a simulation does not replicate the actual accident, it is designed to evaluate specific mechanical and biomechanical issues for similar types of accidents.

Five programs were used to simulate the vehicle dynamics. The software programs were:

- McHenry Simulation Model of Automobile Collisions (m-smac),[12] a two-dimensional analysis of multiple vehicle collisions calculating vehicle deformations and trajectories;
- Engineering Dynamics Corporation Vehicle Simulation Model (EDVSM),[13] a three-dimensional analysis of a single vehicle's response to the driver's inputs, such as steering, throttle, brakes, and gear selection;
- Engineering Dynamics Corporation Vehicle Dynamics Simulator (EDVDS),[14] a three-dimensional simulation of a commercial vehicle's dynamic response to driver inputs and road conditions that can incorporate a tow vehicle and up to three trailers and which is an extended version of the Phase 4 program developed at the University of Michigan;
- Engineering Dynamics Corporation Simulation of Automobile Collisions, (EDSMAC4),[15] a two-dimensional simulation analysis of vehicle collisions based on the "smac" model originally developed by Calspan for the National Highway Traffic Safety Administration (NHTSA) that allows multiple vehicles, trailers, and/or barriers to be analyzed; and
- Engineering Dynamics Corporation General Analysis Tool (EDGEN),[16] a three-dimensional kinematics tool with inputs for eight different vehicle positions and velocities that can calculate the time required to travel between points.

Two programs were used to simulate the occupant kinematics of the representations of fatally or seriously injured bus occupants in the simulated accidents. MAthematical DYnamical MOdels (MADYMO)[17] is a general purpose software package that allows users to perform simulations using both rigid and flexible bodies. This software program enables modeling of an unlimited number of occupants and also incorporates finite element technology. Graphical Articulated Total Body (GATB),[18] developed by Collision Engineering Associates for the Human Vehicle Environment (HVE) system, is a new version of the Articulated Total Body (ATB)[19] program that has been used to analyze occupant kinematics in motor vehicle collisions for approximately 10 years. The GATB uses the graphics built into the HVE system to further the viewing

[12] McHenry Software, Inc., P.O. Box 5694, Cary, North Carolina 27512.

[13] Human Vehicle Environment, Engineering Dynamics Corporation, 8625 S.W. Cascade Boulevard, Suite 200, Beaverton, Oregon 97008-7100.

[14] Engineering Dynamics Corporation.

[15] Engineering Dynamics Corporation.

[16] Engineering Dynamics Corporation.

[17] For further information, see MADYMO User's Manual 3D Version 5.3, TNO Road-Vehicles Research Institute, November 1997. MADYMO simulations conducted for this special investigation were performed in conjunction with National Highway Traffic Safety Administration and Information Systems and Services, Incorporated, a NHTSA contractor.

[18] Grimes, W.D., *Using ATB Under the HVE Environment*, Society of Automotive Engineers Paper No. 970967, 1997.

[19] Obergefell, L.A., Gardner, T.R., Kaleps, I., and Fleck, J.T., *Articulated Total Body Model Enhancements, Volume 2: User's Guide*, Report No. AAMRL-TR-88-043, Armstrong Laboratory, Dayton, Ohio.

capabilities of the ATB program. The maximum number of occupants that the GATB can currently simulate is four (when the Monticello accident was simulated, the GATB's capabilities were limited to one simulated occupant). The GATB also interfaces with the software used for the vehicle simulations, enabling enhanced graphics and ease of implementation.

MADYMO was used to model the Monticello accident, and GATB was used to model the Holyoke and Holmdel accidents.[20] For all three accidents, simulations were performed on unrestrained simulated occupants and on simulated occupants in lap and lap/shoulder belts. The belt attachment points were placed on the base of the seat cushion for the lap belts and on the top of the seatback for the shoulder harness, remaining in that location regardless of the simulated occupant's size. The seatback stiffnesses were not changed for the restrained conditions. The belt attachment points were rigidly fixed throughout the simulation. Default material properties were used for the seats, windows, walls, and belts. For the Monticello accident, the belts were constructed with the available finite elements in MADYMO. For the Holyoke and Holmdel accidents, the belts were defined based on the default belt stiffness characteristics of the HVE system. For further information concerning the assumptions and limitations of these simulations, see appendix C.

Monticello, Minnesota

On April 10, 1997, at approximately 8:11 a.m., a 1995 International Navistar/Thomas Built body 77-passenger school bus was traveling westbound on Wright County Road 39 near the town of Monticello, Minnesota, at a driver-estimated speed of 45 mph. Concurrently, a 1993 Mack tractor with an empty, 4-axle, 29-foot semitrailer was traveling north on Wright County Road 11 at a witness-estimated speed of 50 to 55 mph. The bus was occupied by a 24-year-old lap-belted driver and 13 passengers, ages 6 to 11. A 42-year-old lap/shoulder belt-restrained driver occupied the combination unit.

According to a witness, both vehicles approached the intersection where the tractor-semitrailer failed to stop for the posted stop sign, skidded into the intersection, and was struck by the school bus. At impact, the front of the school bus contacted the right side of the tractor at the right front wheel with approximately 43 inches of overlap. A second impact occurred when the right front corner of the semitrailer struck the left side of the school bus at the roofline, which resulted in a 17.5-inch-deep depression. During the second impact, the tractor's tandem wheels deformed the lower part of the side panel of the school bus. A third impact then occurred, when the semitrailer side-slapped the school bus, which was rotating clockwise as a result of the first two impacts. (See figures 10 and 11.)

[20] The six passengers in the rear of the bus in the Monticello accident, who ranged from 9 to 11 years old, were simulated using the 6-year-old P6 modeled dummy and the Hybrid III 6-year-old modeled dummy. The four passengers in the rear of the bus in the Holyoke accident, who ranged from 8 to 15 years old, were simulated using simulated occupants of similar height and weight to the actual passengers. The four passengers in the front of the bus in the Holmdel accident, who ranged from 7 to 16 years old, were simulated using simulated occupants of similar height and weight to the actual passengers.

Figure 10. Monticello school bus postaccident damage

The truckdriver and three school bus passengers seated in the left rear of the bus were fatally injured. Additionally, one school bus passenger sustained critical injuries, two sustained severe injuries, and three sustained serious injuries. The school bus driver and one passenger sustained moderate injuries, and three passengers sustained minor injuries. Details of the simulation of this accident are provided below.

Simulated Vehicle Dynamics. The m-smac results indicated that the tractor-semitrailer was traveling approximately 49 mph, and the bus was traveling approximately 50 mph at impact. As discussed above, three separate impacts occurred between the bus and the tractor-semitrailer: a frontal impact of the bus into the side of the trailer, a side impact of the semitrailer into the side of the bus, and a side slap of the semitrailer into the side of the bus.

Three of the passengers in the rear of the bus on the driver’s side were fatally injured. Results obtained from the simulations revealed significant differences in the crash pulse and the change in velocity (Delta V) between the center of gravity (CG) of the bus and points at the rear of the bus, possibly contributing to the severity of the injuries to the passengers in the rear. These differences are detailed in table 2. The greatest variance occurred during the last collision when the semitrailer side-slapped the rotating bus. As a result of this collision, the change in velocity at the rear of the bus, according to the simulation, was 44 mph versus 12 mph at the bus’ center of gravity. During the same collision, portions of the bus forward of the center of gravity underwent a smaller change in velocity than did portions at the center of gravity, correlating again with the severity of the injuries sustained by passengers in that region of the bus.

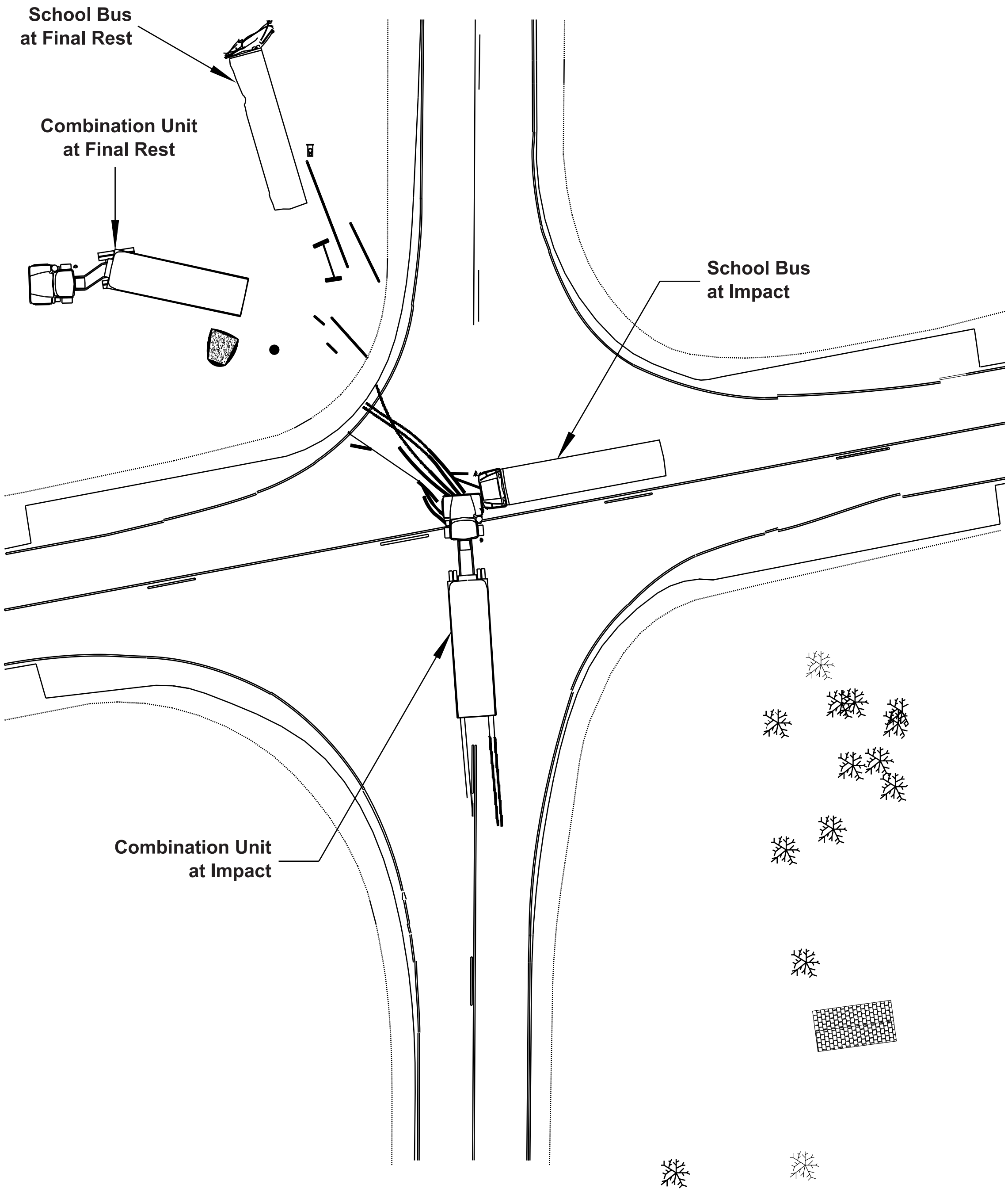

Figure 11. Monticello accident scene diagram

Simulated Occupant Kinematics. In general, the simulated occupants in the rear of the bus first went forward in their seats and then contacted the seats in front of them with their legs, chest, and head. (See figure 12 for a time history of the unrestrained, lap belt, and lap/shoulder belt simulation conditions.) Due to the bus' clockwise rotation, the simulated occupants then slid toward the right side of the bus. Passengers seated on the right side of the bus quickly contacted the side of the bus and the windows and stayed in

Table 2. Peak velocity changes at various locations along the bus in the Monticello accident

Impact	Delta V (mph)	
	Center of Gravity	Left Rear Corner
1st	31	34
2nd	18	18
3rd	12	44

that position until the third impact (side slap) of the bus and semitrailer. Passengers originally seated on the left side of the bus struck the edges of the adjacent seats and also hit other simulated occupants during the motion. The clockwise rotation of the bus continued until the third impact of the bus with the semitrailer. This impact started a counterclockwise rotation of the bus and, therefore, caused the simulated occupants to slide back toward the left side of the bus. The passengers originally seated closest to the left side of the bus impacted the windows and the side of the bus, typically with their heads or upper torsos. Passengers originally seated further from the left side of the bus struck other simulated occupants while sliding toward the left, toward the impacting semitrailer.

The bus' rotation caused the opposite motion for simulated occupants in the front of the bus. Those simulated occupants first went forward in their seat and again contacted the seat in front. The simulated occupants then slid toward the left side of the bus. Simulated occupants on the left side of the bus contacted the side of the bus and the windows quickly, while those on the right collided with those already on the left side of the bus.

When restrained by a lap belt, the simulated occupant's pelvis was essentially fixed to the seat, causing the upper torso to whip sideways. This whipping action, in turn, caused the simulated occupants seated opposite the impact area (seats 11F and 13F in figure 13) to pivot about the pelvis and strike their heads and torsos on the seat cushions. Head injuries were predicted from these impacts. In addition, due to the seats' configuration and the dynamics of the bus, the simulation predicted hyperextension of the neck as simulated occupants on both sides of the bus rotated about the seatback.

Simulated occupants wearing lap/shoulder belts displayed similar kinematics as those restrained by lap belts alone.[21] During the final impact, the side slap, the upper torsos of simulated occupants seated opposite the impact area (seats 11F and 13F) slid out from their shoulder belts. Previous research[22,23] has indicated that the upper torso may slide from

[21] For all simulated occupants, the shoulder portion of the lap/shoulder belt was anchored in the outboard positions of the bus seat, with the upper anchorage always mounted on the outside of the seatback.

[22] Cesari, D., Quincy, R., and Derrien, Y., *Effectiveness of Safety Belts Under Various Directions of Crashes*, Society of Automotive Engineers Paper No. 720973, 1972.

[23] Horsch, J., *Occupant Dynamics as a Function of Impact Angle and Belt Restraint*, Society of Automotive Engineers Paper No. 801310, 1980.

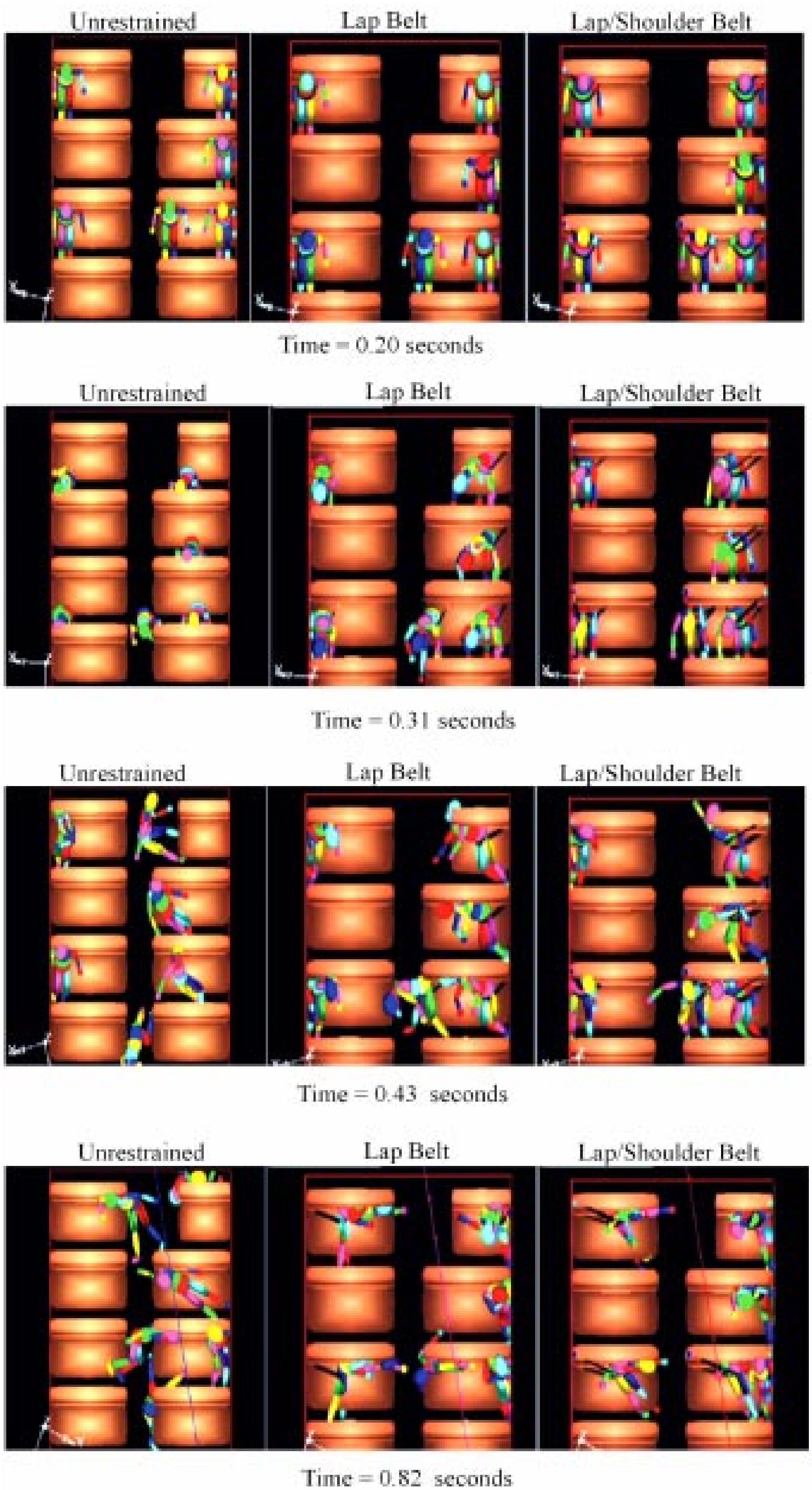

Figure 12. Monticello simulation time sequence history (various restraint conditions)

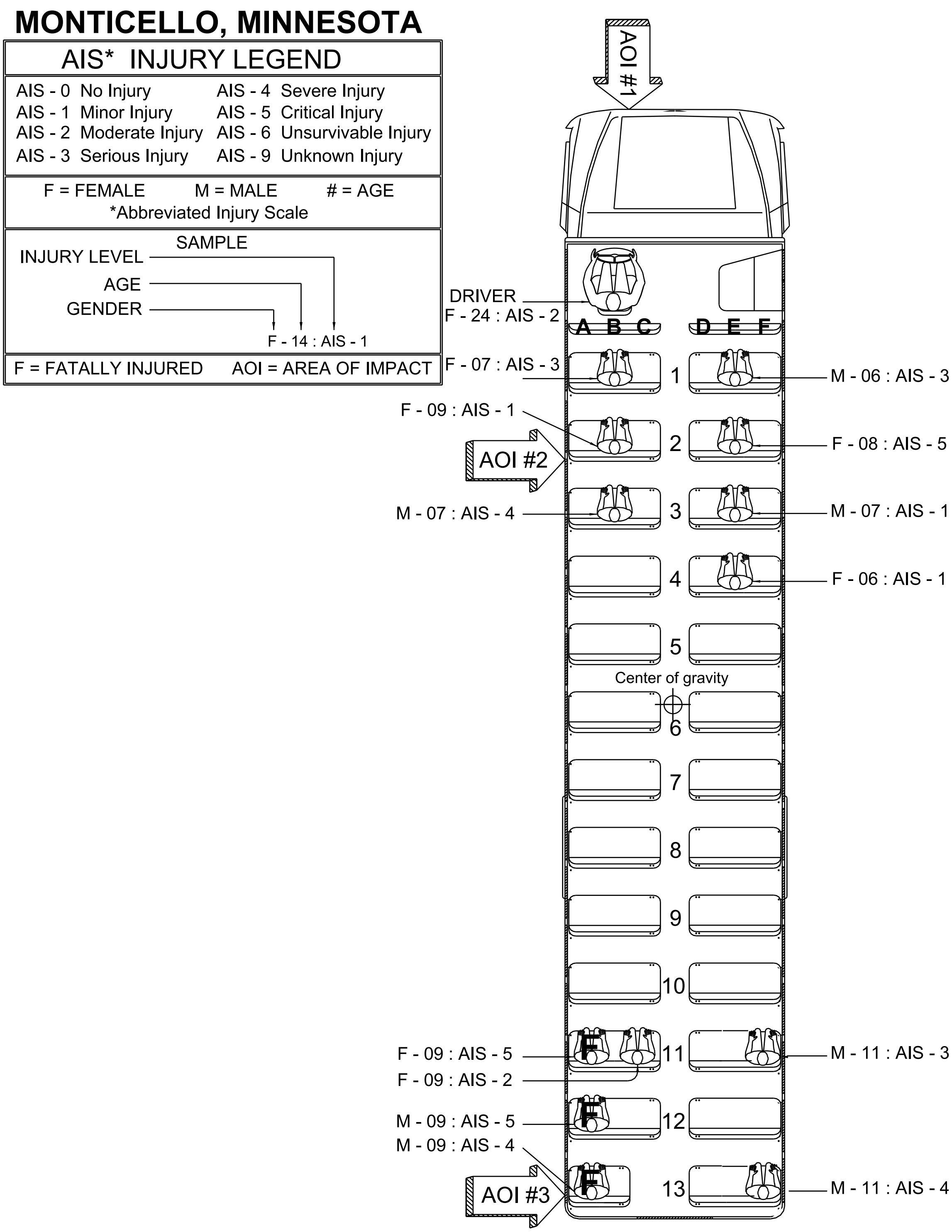

Figure 13. Monticello bus seating diagram

the restraint during side-impact scenarios. These simulations indicate that a potential for head injury exists when the torso slides from the upper restraint. The predicted injuries from the simulation in each of the three restraint conditions and the actual injuries sustained by the bus passengers are summarized in table 3.

Table 3. Summary of actual injuries to the Monticello bus occupants and of predicted injuries based on various simulation conditions

			Predicted Injuries to Simulated Occupants		
Seating Location	**Body Segment**	**Actual Injuries**	**Unrestrained**	**Lap Belt**	**Lap/Shoulder Belt**
11A (fatality)	**Head**	✓	✓	✓	✓
	Thorax	✓	✓		✓
	Neck		–		
11C	**Head**				✓
	Thorax		✓		
	Neck		–		
11F	**Head**			✓	
	Thorax	✓		✓	
	Neck		–	✓	
12A (fatality)	**Head**	✓	✓	✓	✓
	Thorax	✓	✓	✓	
	Neck	✓	–	✓	
13A (fatality)	**Head**	✓	✓		✓
	Thorax	✓	✓	✓	✓
	Neck		–	✓	✓
13F	**Head**			✓	✓
	Thorax	✓		✓	✓
	Neck		–		✓

✓Predicted injury based upon simulation.
– Data unavailable. Neck injuries were not examined in the unrestrained condition.

In the unrestrained condition, three simulated occupants were predicted to sustain head injuries. These simulated occupants represented the fatally injured passengers during the actual accident (seats 11A, 12A, and 13A). Four simulated occupants wearing lap belts were predicted to sustain head injuries; five simulated occupants wearing lap/shoulder belts were predicted to sustain head injuries. During the restrained conditions, simulated occupants seated on the side of the bus opposite the impact area were predicted to sustain injuries from the head's impact onto the seat cushion as the upper body whipped about the fixed pelvis.

The simulation predicted chest accelerations for four unrestrained simulated occupants, four lap-belt restrained simulated occupants, and three lap/shoulder belt-restrained simulated occupants. Neck injuries[24] were predicted for three lap belt-restrained simulated occupants and two lap/shoulder belt-restrained simulated occupants.

This simulation indicates that caution should be exercised when placing lap belts or lap/shoulder belts on school buses without altering the configuration of the seats to restrain the upper body during side impacts. Injuries could potentially result with belt usage that would not have resulted with compartmentalization alone.

Holyoke, Colorado

On September 1, 1998, approximately 3:45 p.m., a 1986 International Navistar/Blue Bird body, 54-passenger school bus began to accelerate from a stop in the eastbound lane of Highway 6, near Holyoke, Colorado, when it was struck in the rear, on the left side, by the right front of a 1992 Peterbilt tractor pulling an empty semitrailer. The bus was occupied by a 42-year-old lap-belted driver and 12 passengers, ages 7 to 15. The bus rotated 180 degrees clockwise then overturned onto its left side. A 15- and an 8-year-old bus passenger were ejected from the rear of the bus.[25]

The semitrailer struck the rear left side of the of the school bus. The bus was traveling approximately 5 mph at the time of the impact, after reportedly letting one passenger off the bus at a bus stop; the tractor was traveling approximately 50 mph. At impact, the front of the bus accelerated forward and then began to rotate clockwise while the tractor-semitrailer decelerated rapidly and continued to swerve to the left. As the bus continued to rotate, the left rear bus tire dug into the pavement, creating a deep gouge. After rotating approximately 180 degrees in a clockwise direction, as seen from above, the bus rolled counterclockwise (90 degrees about the long axis of the bus) onto its left side into the ditch parallel to the roadway. The tractor rotated out to the left side of the roadway with the trailer swinging out behind it. The vehicle came to rest with the tractor and semitrailer across both lanes of traffic. (See figures 14 and 15.)

None of the vehicle's passengers was fatally injured. Nine bus passengers sustained minor injuries, one passenger sustained moderate injuries, one passenger sustained critical injures, and one passenger and the busdriver were not treated. Details of the simulation of this accident are provided below.

Simulated Vehicle Dynamics. The simulations revealed that before braking to avoid hitting the rear end of the bus, the tractor-semitrailer was traveling approximately 60 mph, which was below the posted speed limit of 65 mph. In addition, the bus had probably just started to accelerate before the accident after dropping off one passenger. The change in velocity as a result of this collision was 25.2 mph for the bus and 17.1 mph for the truck. Because the bus underwent changes in angular velocity during the collision, the total change in velocity experienced by different portions of the vehicle away from the

[24] Because the extreme kinematics contributing to neck injuries were not noted in the unrestrained condition and because the modeling software did not have the capability to measure neck injuries at the time of the unrestrained simulation, neck injuries were not examined for the unrestrained condition.

[25] According to witness interviews, these two occupants may have been standing in the aisle before impact.

Figure 14. Holyoke school bus postaccident damage

center of gravity of the vehicle varied. Table 4 details the change in velocity at the center of gravity of the bus and also at the left rear corner of the bus, where the two ejected passengers were located.

During the rollover, different accelerations were again experienced along the length of the bus. The accelerations were much lower than the accelerations seen in the Monticello simulation, indicating the reduced level of severity of this accident. Table 5 details these accelerations and the positions inside the bus.

Simulated Occupant Kinematics. In general, the simulated occupants first traveled backward in the bus. Seated simulated occupants contacted the back of the seat. Unseated simulated occupants continued to travel backward, toward the passenger side of the bus, due to the bus' rotation, until contacting a surface such as the sides of seats and the rear emergency exit door. As the bus continued to rotate and tip over on its side, the simulated occupants began to slide toward the driver's side of the bus, where they subsequently contacted the sides of the seats (since the seats were not directly opposite one another across the center aisle), the side wall of the bus, or other simulated occupants.

The ejection path and rest positions of the two ejected passengers (seats 8C and 9C in figure 16) were most closely matched by the simulated occupants when they stood in the aisle before impact. (See figure 17.) A slight opening of the rear emergency exit door facilitated the complete ejection of these simulated occupants.[26] Higher injury levels were seen for the two reportedly ejected simulated occupants in the standing position than in the seated position because they were not protected by the seating compartment. Although the bus' accelerations were low, the simulated standing occupants contacted surfaces inside

[26] Witness and passenger reports were not clear concerning whether the emergency exit door of the school bus had opened during the accident or was opened by rescue workers after the accident. Therefore, the opening of the rear emergency exit door was investigated for each of the seating positions. The door position variations simulated were closed, partially (30 degrees) open, and fully open. Impact forces may have changed the position of the door, but the exact door reactions are unknown.

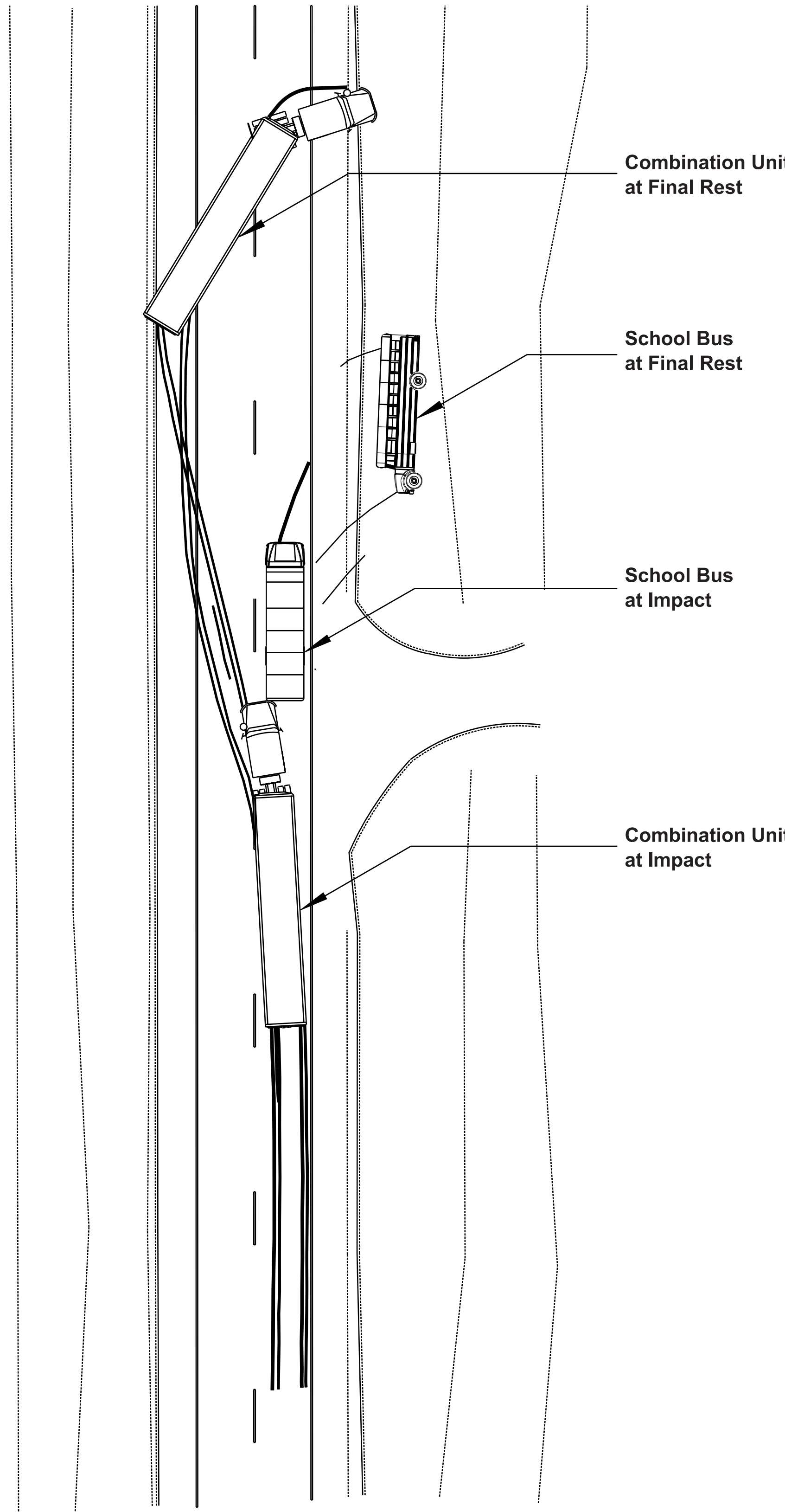

Figure 15. Holyoke accident scene diagram

Table 4. Peak velocity changes at various locations along the bus in the Holyoke accident

Direction	Delta V (mph)	
	Center of Gravity	Left Rear Corner
Longitudinal	14	30
Lateral	4	0
Total*	25	40

* Total Delta V determined by the integration of resultant acceleration.

Table 5. Accelerations experienced inside the bus during the rollover sequence in the Holyoke accident

Position	Acceleration (g)			
	Longitudinal	Lateral	Vertical	Total
Center of Gravity	0.0	2.6	-1.6	3.2
Seat 8C	-0.1	5.7	-0.3	5.8
Seat 8F	1.3	4.1	-4.8	6.8
Seat 9C	-0.1	6.5	-0.6	6.6
Seat 9F	1.4	4.8	-5.2	7.2

the vehicle and outside the vehicle not designed to absorb energy and thus were predicted to sustain injury.

Similar kinematics were noted for both unrestrained and restrained simulated occupants in the seated, forward facing condition, except that for lap-belted simulated occupants,[27] the pelvis was belted to the seat. During the bus' rotation and the subsequent rollover, lap-belted simulated occupants pivoted about the pelvis and then contacted the seat cushion with the upper body. Predicted injury values were low during this sequence for all restraint conditions, presumably due to the low accelerations of the bus.

The predicted injuries from the simulation for the two unrestrained conditions, the two restrained conditions, and the actual injuries sustained by the bus passengers are shown in table 6.

During the unrestrained simulation of the two reportedly ejected passengers (seats 8C and 9C) standing in the aisle, the two standing simulated occupants were predicted to sustain head injuries. In addition, the simulated occupant in seat 9F was predicted to sustain head injuries as the bus overturned and interaction occurred between simulated

[27] For all simulated occupants, the lap/shoulder belt ran from the lower-left side of the simulated occupant to the upper-right side of the simulated occupant. (All simulated occupants were seated on the right side of each bus seat.) Due to this configuration, the upper bodies of the simulated occupants were noted to slide from the shoulder restraint as the bus began to overturn. Thus, in this accident, the lap/shoulder belts functioned similarly to lap belts.

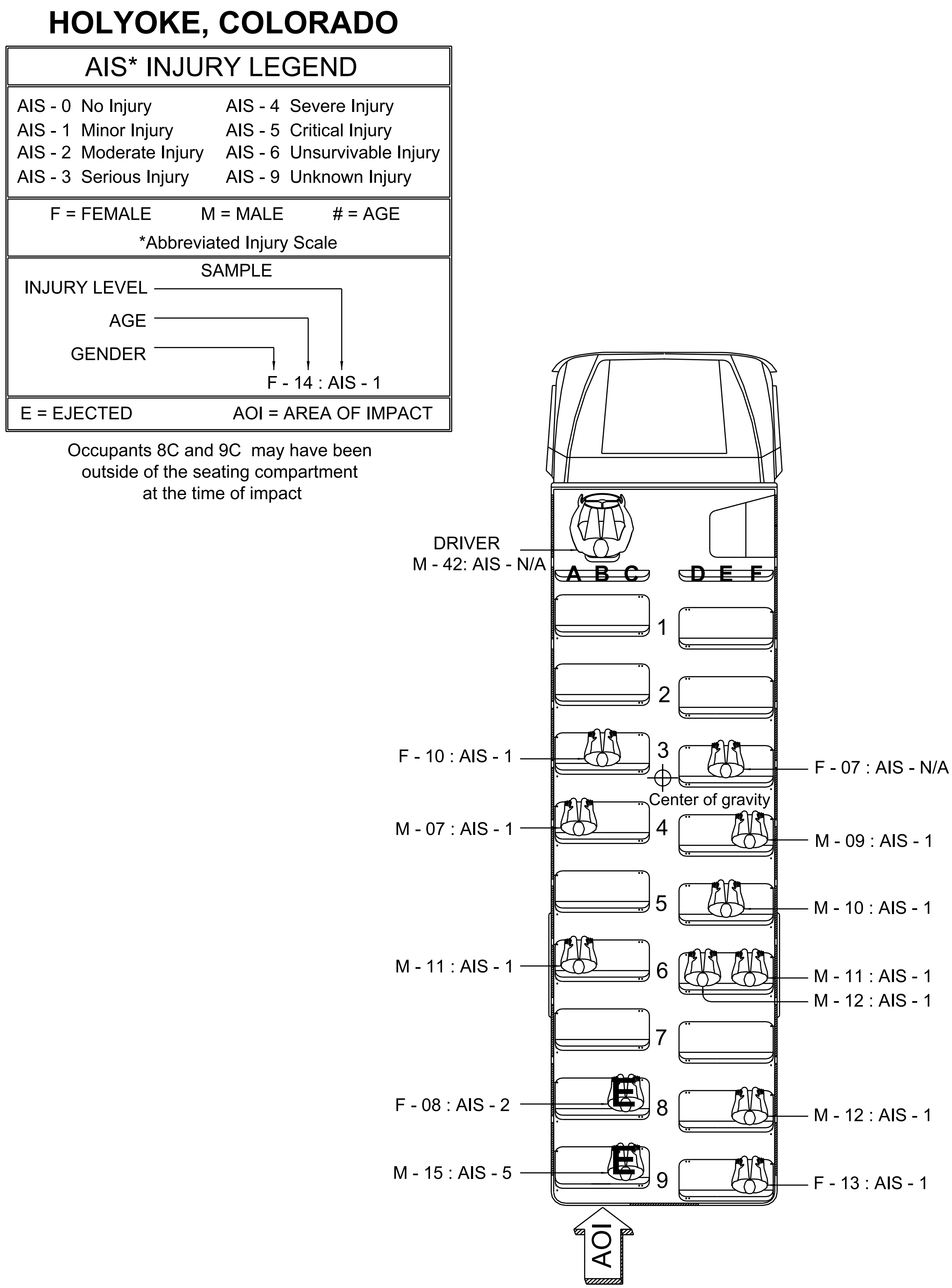

Figure 16. Holyoke bus seating diagram

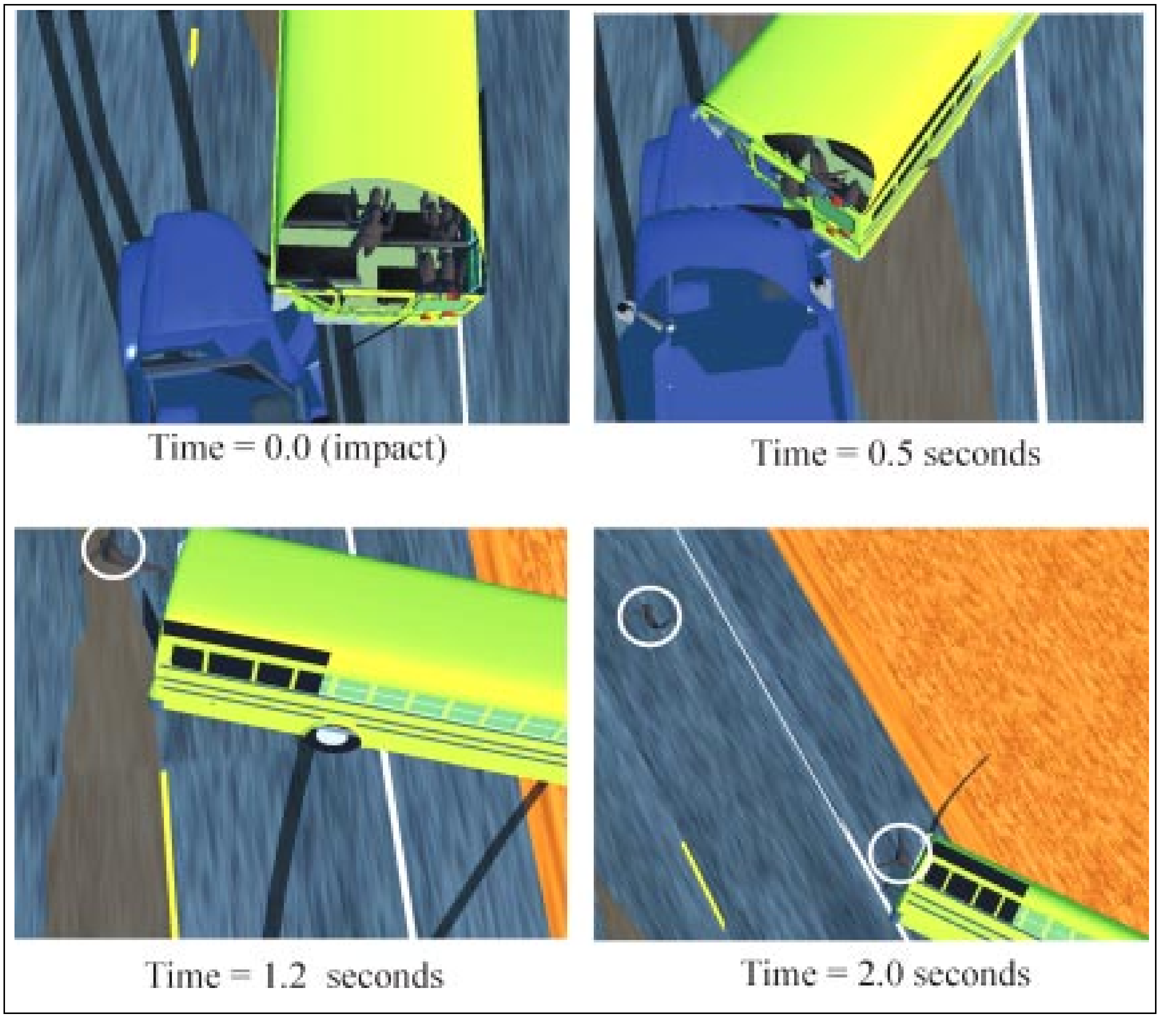

Figure 17. Holyoke simulation time sequence history

occupants. When the two simulated occupants (seats 8C and 9C) were seated, only the simulated occupant in seat 8C was predicted to sustain a head injury, which would have occurred as the head contacted the side window during the overturn sequence. Head injuries were not predicted for any restrained simulated occupant. Chest accelerations were predicted only for the standing simulated occupant near seat 9C. Neck injuries were not predicted for any of the simulated occupants in any condition.

The results of this simulation indicate that the majority of the force causing the simulated occupants to be propelled rearward in the vehicle occurred early in the accident sequence, as the tractor-semitrailer initially impacted the bus. Therefore, simulated occupants who were within the seating compartment, even partially, did benefit from the compartmentalization because the rearward velocity was decreased as they contacted the seatback. This decrease in rearward velocity reduced the likelihood of ejection out of the rear emergency exit door in this accident.

Table 6. A summary of actual injuries to the Holyoke bus occupants and of predicted injuries based on various simulation conditions

			Predicted Injuries to Simulated Occupants			
Seating Location	**Body Segment**	**Actual Injuries**	**Unrestrained (seated, facing forward)**	**Unrestrained (8C and 9C standing)**	**Lap Belt**	**Lap/Shoulder Belt**
8C (ejected)	**Head Thorax Neck**	✓	✓	✓		
8F	**Head Thorax Neck**					
9C (ejected)	**Head Thorax Neck**	✓ ✓		✓ ✓		
9F	**Head Thorax Neck**			✓		

Holmdel, New Jersey

On September 18, 1998, approximately 7:18 a.m., a 1990 Ford/Thomas Built body, 54-passenger school bus was traveling eastbound on County Road 520 in Holmdel, New Jersey, approaching the intersection with State Route 34. The bus was occupied by a 26-year-old unrestrained driver and six passengers, ages 7 to 16. Concurrently, a 1979 Mack, fully loaded dump truck was traveling south on State Route 34 at a driver-estimated speed of 40 to 45 mph.

The school bus driver, attempting to make a left turn, entered the intersection on a red traffic signal and was struck by the truck. The front of the truck contacted the left side of the school bus at the left front tire. The bus rotated clockwise, and a secondary impact occurred between the left side of the bus and the right side of the truck. Following the accident, the truck overturned onto its right side.

The dump truck impacted the driver's side of the school bus slightly in front of the driver's seat. After striking the school bus, the dump truck began to rotate counterclockwise. The school bus rotated clockwise and a secondary impact occurred between the left side of the bus and the right side of the truck. The majority of the damage occurred on the driver's side of the bus near the driver's seat, between approximately the fifth and sixth rows, where the dump truck overturned onto the top and edge of the bus, creating a puncture hole. (See figures 18 and 19.)

The busdriver sustained severe injuries during the accident. One passenger sustained serious injuries. Two passengers sustained moderate injuries, and three passengers sustained minor injuries. The passenger seats in the school bus were not equipped with seat belts. Details of the simulation of this accident are provided below.

Figure 18. Holmdel school bus postaccident damage

Simulated Vehicle Dynamics. The simulations indicate that the truck was traveling at approximately 41 mph before impact. The truck began to steer left about 2.6 seconds before impact and then struck the school bus on the left side behind the front left tire while traveling at a speed of approximately 38.5 mph. The truck experienced an estimated change in velocity of 11.8 mph and an estimated peak acceleration of 11.3 g at the center of gravity.

The school bus was traveling approximately 22 mph when it began to turn into the intersection and approximately 21.3 mph at impact. The bus' change in velocity was estimated at 39.4 mph, and the peak acceleration for the bus was calculated to be 37.9 g at the center of gravity, an acceleration greater than that calculated for the Monticello accident.

The accelerations at different locations inside the bus were also investigated during this reconstruction. Table 7 details the accelerations experienced at the bus' center of gravity as well as at the driver's seat and on the left and right sides of the first row of passenger seats. The maximum acceleration at the center of gravity occurred slightly before the maximum acceleration of the simulated accelerometers placed on the passenger seats. Therefore, both acceleration values are reported in table 7. The values indicate that the accelerations at the driver's seat were greater than those experienced in the row directly behind the driver. In addition, at these seats, the accelerations were predominantly lateral.

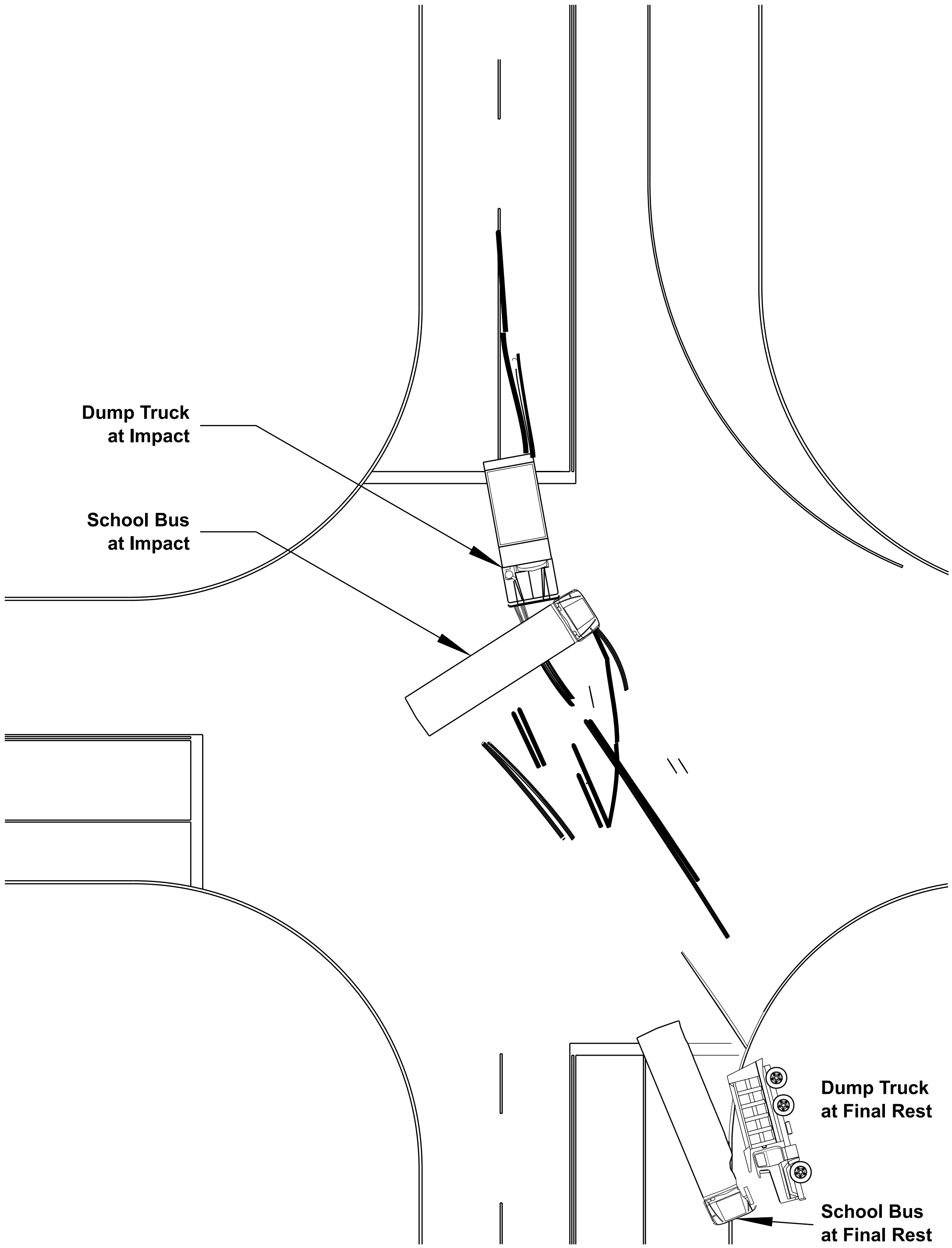

Figure 19. Holmdel accident scene diagram

Simulated Occupant Kinematics. The simulated occupant kinematics experienced during this accident were similar to those seen in the simulation of the Monticello accident. In general, the simulated occupants first went diagonally toward the driver's side of the bus and slightly forward. (See figure 20.) Those simulated occupants originally located on the driver's side of the bus (the side contacted during the collision

Table 7. Peak accelerations experienced inside the bus in the Holmdel accident

Position	Acceleration (g)		
	Longitudinal	Lateral	Total
Center of Gravity	-10.3	25.8	28.0
Driver's Seat	1.2	18.3	18.4
Row 1 Left Side	2.9	11.2	11.6
Row 1 Right Side	-4.4	11.0	11.9
CG Maximum	-30.1	22.9	37.9

with the dump truck) quickly contacted the side of the bus and the windows. Those on the opposite side slid across the seat toward the driver's side, contacting the seat in front (or the modesty panel) and the sides of the seatbacks (or of the modesty panel), and then continued into the row in front of the original seating location due to the bus' kinematics.

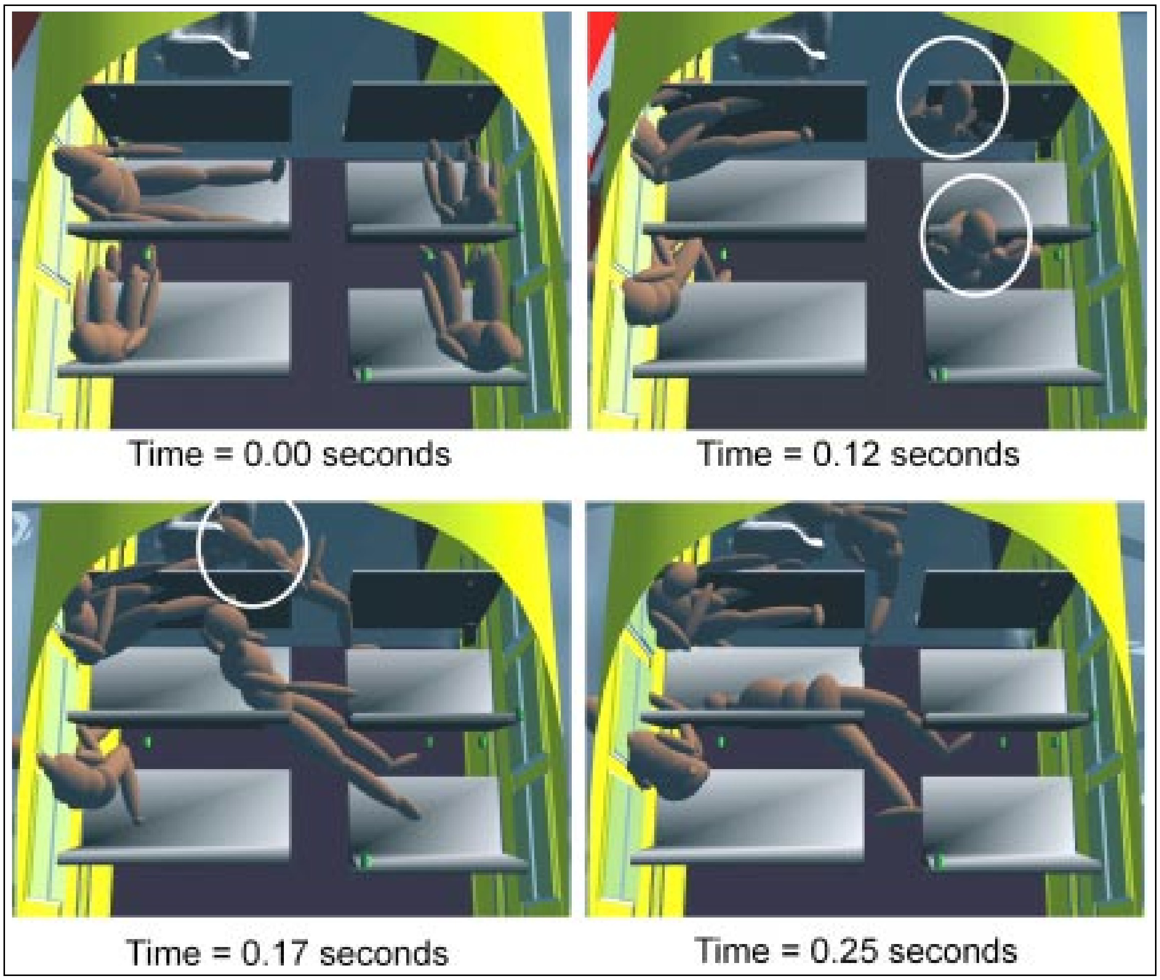

Figure 20. Holmdel simulation time sequence history (unrestrained condition)

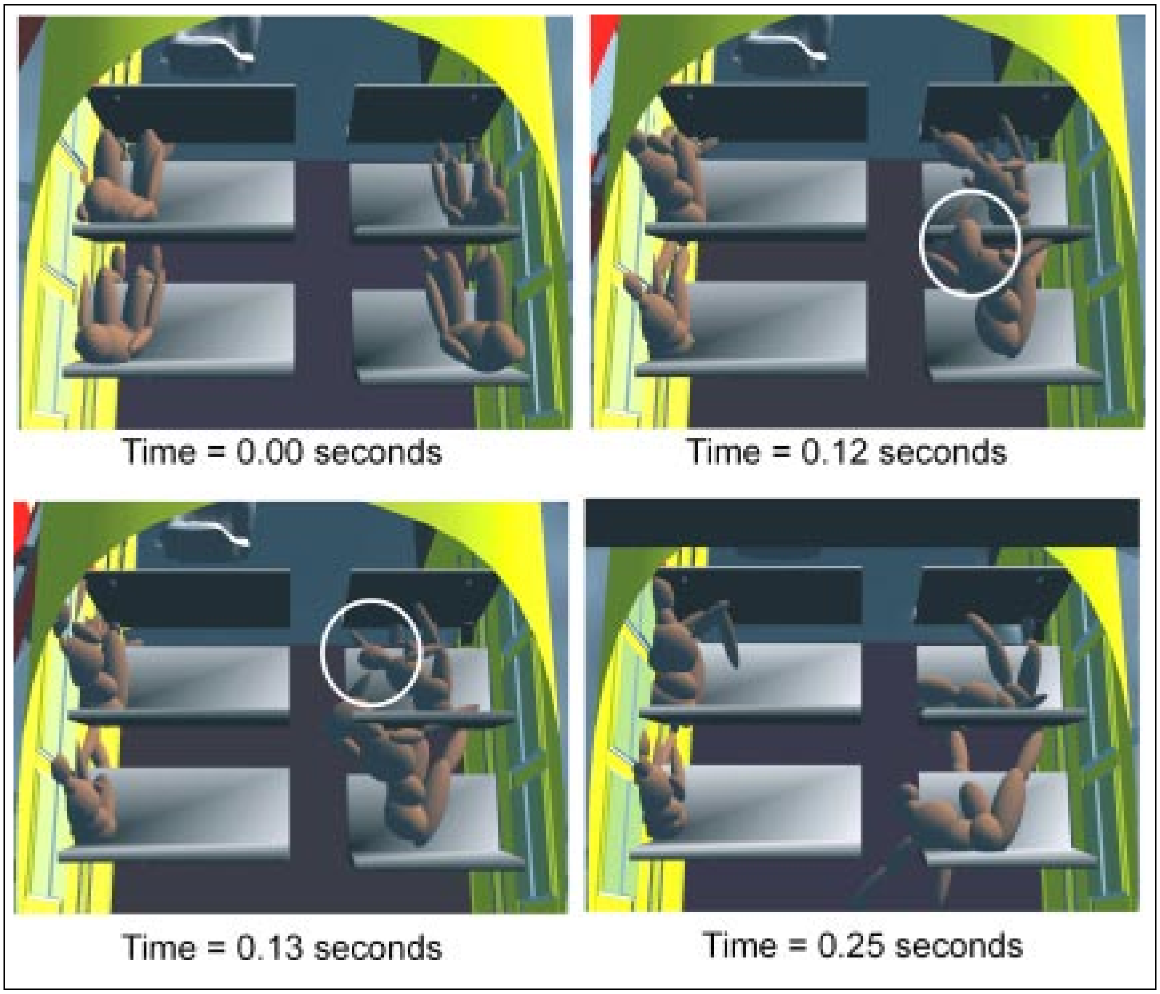

Figure 21. Holmdel simulation time sequence history (lap belt-restrained condition)

The lap belt in this simulation restrained the pelvis of the simulated occupant to the seat. (See figure 21.) For the two simulated occupants on the opposite side of the bus from the impact, the kinematics were dramatically altered from the unrestrained condition. The simulated occupant in seat 1E (see figure 22) did not contact the modesty panel as in the unrestrained condition. Instead, this simulated occupant rotated about the pelvis and struck the seat cushion with the head, resulting in a predicted head injury. (The predicted head injury level in the lap belt-restrained condition was lower than the predicted head injury level in the unrestrained condition.) Similarly, the simulated occupant in seat 2E rotated about the pelvis, but because this simulated occupant was larger than the simulated occupant in 1E, the simulated occupant in seat 2E contacted the seatback in front with the head concentrating the force of the impact in a small region. This impact resulted in a predicted head injury for this simulated occupant.

Those simulated occupants on the same side of bus as the impact displayed similar kinematics to those in the unrestrained condition but had higher predicted injury levels. The lap belt again acted to restrain the pelvis of these simulated occupants to the seat and thus allowed smaller portions of the body to absorb the impact energy.

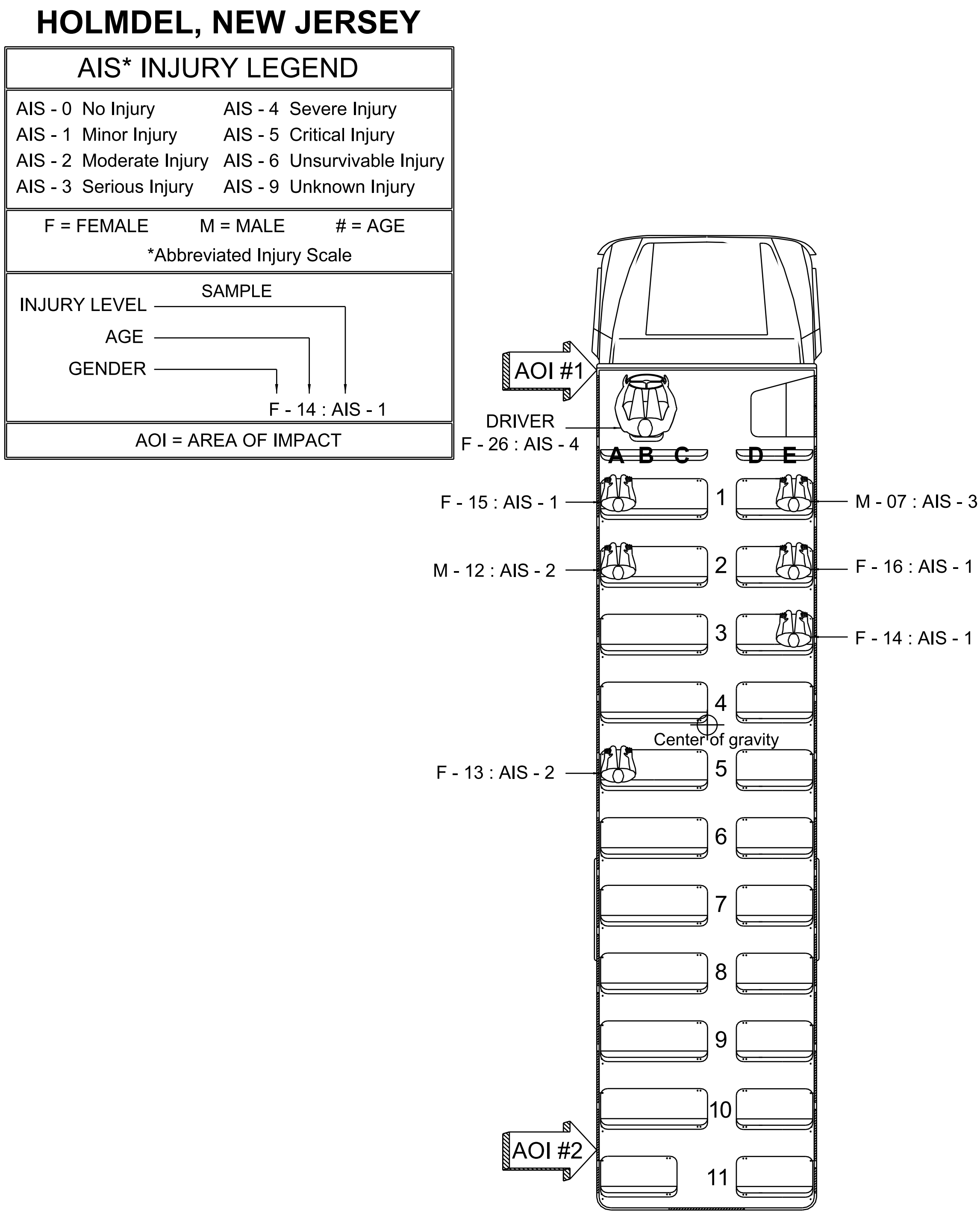

Figure 22. Holmdel bus seating diagram

In the lap/shoulder belt-restrained condition, although the chest acceleration values were higher than in the unrestrained condition, the simulated occupants on the opposite side of the bus from the impact (seats 1E and 2E) were not predicted to sustain head injuries because the shoulder harnesses were able to restrain the upper torso and thus protect the simulated occupants' heads from impacts within the vehicle. (See figure 23.) The upper torso did slide from the shoulder restraint, but the trajectory of the upper body was forward and lateral, whereas for the Monticello accident it was predominately lateral (as discussed earlier.) Therefore, the velocity of the upper body was reduced enough to prevent injury before the upper torso slid from the belt. For the simulated occupants on the same side as the impact (seats 1A and 2A), the levels of predicted injury were similar to those in the lap belt-restrained condition, although both simulated occupants were predicted to sustain neck extension injuries in this restraint condition.

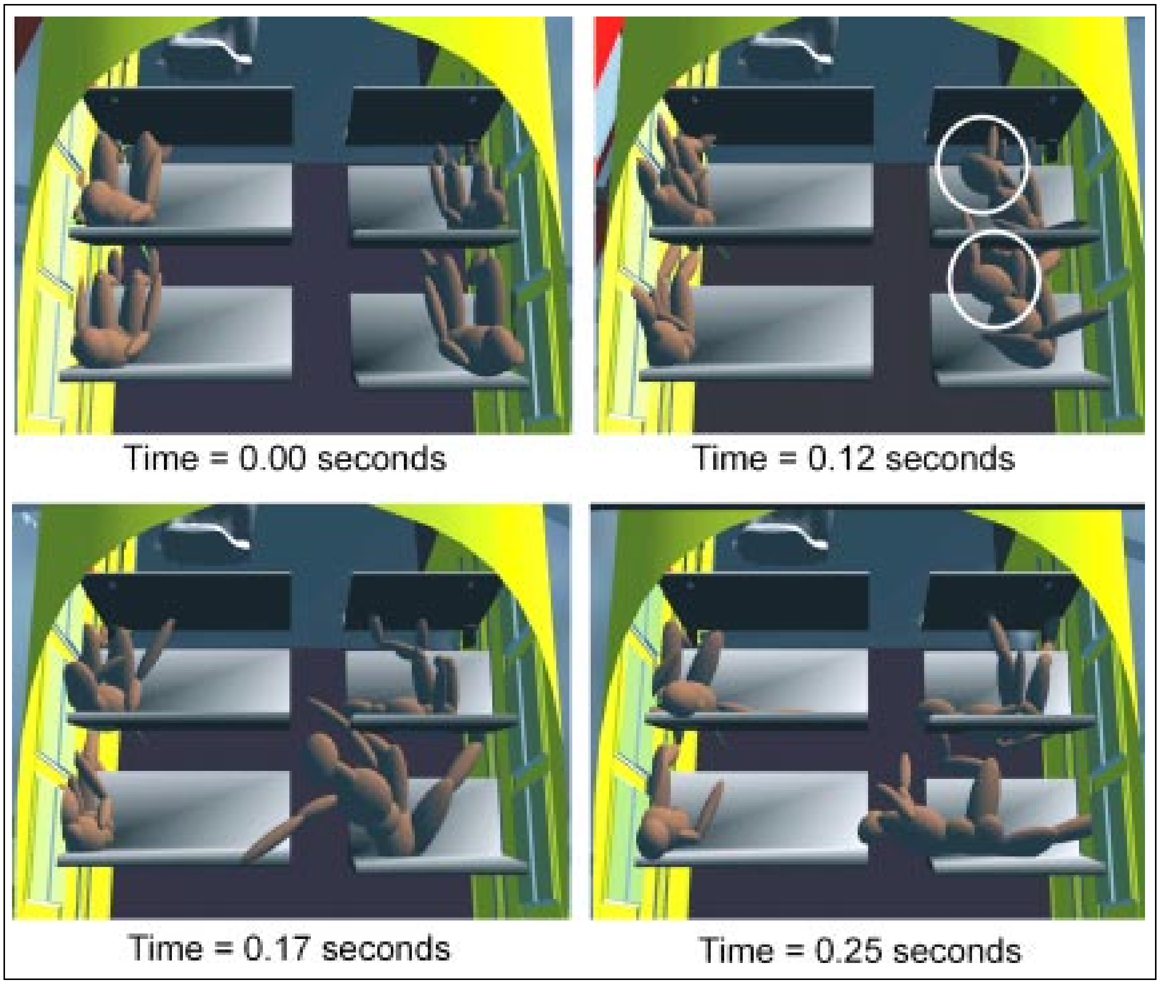

Figure 23. Holmdel simulation time sequence history (lap/shoulder belt-restrained condition)

The predicted injuries from the simulation for each of the three restraint conditions and the actual injuries sustained by the bus passengers in the actual accident are summarized in table 8. These predicted injuries for the unrestrained condition reflect the kinematics of the sideways positioned simulated occupant in seat 1A. (This orientation was reported by the passenger seated in 1A.) The simulated occupant in seat 1A was also placed seated forward facing to enable comparisons to the restrained condition in which passengers must be forward facing in the simulation.

Table 8. Summary of actual injuries to the Holmdel bus occupants and of predicted injuries based on various simulation conditions

			Predicted Injuries to Simulated Occupants		
Seating Location	**Body Segment**	**Actual Injuries**	**Unrestrained (1A sideways)**	**Lap Belt**	**Lap/Shoulder Belt**
1A	**Head**			✓	✓
	Thorax		✓	✓	✓
	Neck				✓
1E	**Head**	✓	✓	✓	
	Thorax		✓	✓	✓
	Neck		✓	✓	
2A	**Head**			✓	✓
	Thorax	✓	✓	✓	✓
	Neck				✓
2E	**Head**			✓	
	Thorax			✓	✓
	Neck				✓

For the unrestrained condition (forward facing in seat 1A), two simulated occupants were predicted to sustain head injuries. In the lap belt-restrained condition, all four simulated occupants were predicted to sustain head injuries; in the lap/shoulder belt-restrained condition, two simulated occupants were predicted to sustain head injuries. All simulated occupants in all restraint conditions except one, seat 2E in the unrestrained condition, were predicted to sustain chest acceleration values. The unrestrained simulated occupants were not predicted to sustain neck injuries. One simulated occupant wearing a lap belt was predicted to sustain a neck injury, while three simulated occupants wearing lap/shoulder belts were predicted to sustain neck injuries.

Again, the results of this simulation indicate that both lap belts and lap/shoulder belts may result in injuries not previously seen with compartmentalization alone. The lower head injury values for the simulated occupants in seats 1E and 2E, as simulated wearing a lap/shoulder belt, indicate that the potential exists to decrease injuries with some form of restraint system. Still, care must be exercised to prevent simulated occupants, who may have sustained minor injuries unrestrained, from being further injured because of restraints.

School Bus Occupant Crash Protection Systems

In analyzing the most recent large school bus accidents, alternative restraint systems were investigated that may have mitigated injuries for certain passengers in particular accidents. However, it may not be possible to accurately predict the level of injury that would have occurred had a given restraint system been used. Even with a detailed reconstruction of the accident, the crash pulse experienced by an occupant is difficult to determine. Lacking this basic information, the speed and direction of an occupant within the vehicle and the occupant’s impact force onto a contact surface within the vehicle cannot be known exactly. Assumptions must be made that a restraint system was used properly (the seat belt was not initially positioned on the abdomen or placed against the neck) and that the passenger was seated with correct/ideal posture (front facing, feet on floor). These assumptions may be critical. An improperly used restraint system may actually cause more injuries than it prevents.

Intrusion into the bus by the other vehicle is also an important consideration when analyzing the performance of restraint systems. In the Large School Bus Study, the Safety Board noted that the most critically injured passengers were seated in the impact zone. During a collision with multiple impacts, however, the forces of the initial impact may propel the passenger away from the area of intrusion as the secondary intrusion occurs. To analyze the severity of injury of a restrained versus an unrestrained occupant requires comparing the severity of injury due to the intrusive forces of another vehicle into the bus with the forces experienced by the occupant if propelled from the impact zone. Thus, a highly accurate simulation is required to determine what the optimal occupant protection would have been for a specific accident.

Current Occupant Crash Protection

One method by which current poststandard school buses protect the passenger is through compartmentalization. By virtue of its design, current compartmentalization is most effective in protecting occupants in frontal and rear impacts in that it keeps the passenger within the seating compartment. As was discussed earlier, compartmentalization is accomplished by spacing the seats closely together and by covering the seat cushions and high seatbacks with an energy-absorbing material. The entire seat structure is designed to absorb energy and deform to dissipate the energy of the crash away from the passenger and into the surrounding compartment. The Safety Board's 1987 Large School Bus Study concluded that current compartmentalization worked well in the Safety Board-investigated accidents to protect school bus passengers from injuries in all types of accidents. However, the study also added a caveat regarding three side-impact (nonrollover) accidents that were investigated:

> Unfortunately, due to the nature of these accidents [two minor sideswipe accidents, one involving a bus equipped with lap belts, and one moderate grade-crossing accident] and the limited data they provided, no judgments as to the level of occupant protection provided to unrestrained schoolbus passengers in side impacts could be made, nor could any judgments as the value of lap belts in side impact be made.

In addition, the 1987 study found that most passengers who were fatally or seriously injured were seated in the area of intrusion and would not have benefited from being restrained in their seats.

In this special investigation, four of the school bus accidents[28] the Safety Board investigated were lateral impacts with vehicles of large mass. The Safety Board believes that the passengers who were retained within the seating compartment (and not in the area of intrusion) during the accident sequence benefited from compartmentalization

[28] Easton, Maryland; Buffalo, Montana; Monticello, Minnesota; and Holmdel, New Jersey.

distributing the impact energy to surfaces designed to absorb that energy. Passengers not retained within the compartment (not initially in the area of intrusion) impacted surfaces within the bus not designed to absorb energy. For example, in the Holmdel accident, two passengers seated just behind the intrusion area remained within the compartment throughout the accident sequence. Those two passengers sustained minor to moderate injuries, while the passenger seated on the side opposite the impact sustained serious injuries as a result of impacting surfaces located outside the compartment. The Safety Board concludes that school bus passengers who remained within the seating compartment but not within the intrusion area during the accident sequence were less likely to have been seriously injured than passengers who were out of the compartment before the collision or who were propelled from the compartment during the collision.

The Safety Board is concerned that current compartmentalization, because of its design, does not protect all passengers during lateral impacts with vehicles of large mass and during rollovers, especially passengers seated outside the impact area. Occupant motion analysis of these accidents found that these passengers were being thrown from the seating compartment toward the area of impact. In addition, if a school bus was hit on the side or began to rotate during the accident, the passenger may not have directly contacted the seatback or the seat in front but instead may have slid laterally on the seat. During this movement, the passenger would have encountered either another passenger, the side walls, the windows, or the edge of an adjacent seat. Unlike the seating compartment, none of these surfaces are designed to absorb impact energy. Consequently, passengers striking these surfaces have a greater chance of injury than when striking the seatback from behind. This tendency for higher injury could be seen in the Holyoke accident simulation, where the standing simulated occupants were predicted to impact the rear emergency door, resulting in a high risk of injury. In the same simulation, those seated within the energy-absorbing compartment adjacent to the standing simulated occupants were predicted to impact the seatback, resulting in a low risk of injury. Furthermore, had the bus rolled over during the accident, as in the Flagstaff and Holyoke accidents, the passenger may have impacted the roof of the bus, the luggage rack, or the tops of the seatbacks. Again, such surfaces are not designed for impacts. The Safety Board concludes that, because of compartmentalization, school bus passengers are safer now than they were before 1977. However, recent accidents lead the Safety Board to further conclude that current compartmentalization is incomplete in that it does not protect school bus passengers during lateral impacts with vehicles of large mass and in rollovers because, in such accidents, passengers do not always remain completely within the seating compartment.

Alternative School Bus Occupant Protection

Safety Board staff reviewed information regarding other passenger protection systems for school buses that are available or may be available in the future: a lap/shoulder belt system that can be installed on standard school bus seats, a restraining bar, and a seat with integrated lap/shoulder belts.

A lap/shoulder belt system is currently available that can be retrofitted onto standard school bus seats. Company literature states that the system meets the testing requirements of Federal Motor Vehicle Safety Standard (FMVSS) 222, School Bus

Passenger Seating and Crash Protection,[29] meaning that if a standard school bus seat is retrofitted with a device and if the device does not change the strength of the seat by its installation, it meets FMVSS 222 requirements. Because current seatbacks are designed to deform to absorb the energy of unrestrained occupants, they cannot withstand the loading of three belted occupants without deforming. Consequently, in a frontal impact, these lap/shoulder-belted passengers would deform the seat forward through loading of the restraint system. If an unrestrained passenger were seated behind the belted passengers, that passenger's forward motion would not be stopped by the seatback (which usually occurs in compartmentalization). This unrestrained occupant could then be seriously injured by impacting interior surfaces within the bus and could also seriously injure the restrained occupants in front by deforming the seat downward. There are no standards that an occupant crash protection system must meet when retrofitted onto a school bus seat. Under current regulations, retrofitting is allowed unless it renders FMVSS 222 ineffective.

A restraining bar is being developed that attaches to the seatback in front of the seat where the passengers to be restrained are seated. The bar has an automatic locking feature (pendulum) and looks similar to restraining bars used on amusement park rides. Company literature states that the bar can be retrofitted onto poststandard school bus seats.

The Safety Board is concerned that the bar, because of its design, will not effectively restrain the lateral movement of passengers in collisions. In addition, if two passengers of greatly varying sizes are seated on the same seat, the fit and effectiveness of the restraint for the smaller passenger would be questionable. Further, company literature states that "when the bus is in an upright and stable condition, the bar releases." However, it is not apparent how passengers would release the restraint if the bus were not in this position following a rollover-type accident. A company representative stated that if the bus were in a collision and came to rest on its roof, the passengers should move out from under the bar at the end of the seat, while upside down. In addition, the restraint bar would not be totally effective in preventing ejection. The occupants could still move laterally relative to the seat and, thus, exit the seating compartment and potentially be ejected from the bus.

Also under development is an integrated lap/shoulder belt system and seat that would withstand the loading of two restrained passengers. The seat is contoured for two passengers, with the height-adjusting shoulder portion of the belts anchored in the center of the seat. Company representatives believe that a seat/restraint system can be developed to withstand the loading of the restrained passengers and absorb the energy of unrestrained passengers seated behind the seat without injuring any of the passengers. Although this occupant restraint system is still in development, a prototype has been manufactured and tested in a frontal barrier impact scenario. The company would not provide the results of its testing to the Safety Board.

The Safety Board is concerned that not all alternative school bus occupant protection systems under development provide equal protection. Therefore, the Safety

[29] For further information on FMVSS applicable to school buses, see appendix B.

Board concludes that all potential designs for occupant protection systems to be used on school buses should be tested to uniform performance standards developed by NHTSA to ensure occupant safety. The Safety Board believes that in 2 years, NHTSA should develop performance standards for school bus occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers.

As discussed earlier, if a school bus is involved in an accident with large lateral or rotational forces, current compartmentalization is incomplete and less effective. The Safety Board's investigations showed that passengers seated away from the area of impact may sustain serious injuries as a result of being propelled into the impact area by the collision forces. Therefore, the Safety Board investigated the issue of passenger restraints, using computer simulation and injury analysis to determine whether additional forms of restraint would better protect the passengers in lateral impacts and rollovers.

Simulated occupants restrained by lap and lap/shoulder belts were compared with unrestrained simulated occupants to determine the effectiveness of current restraint systems in large school bus accidents. For example, three simulations were performed for the Monticello accident restraint analysis: unrestrained, lap belt-restrained, and lap/shoulder belt-restrained. In the unrestrained condition, three simulated occupants[30] were predicted to sustain head injuries. In the lap belt-restrained condition, four simulated occupants were predicted to sustain head injuries. In the lap/shoulder belt-restrained condition, five simulated occupants were predicted to sustain head injuries.

In the lap belt-restrained simulation, the lap belt restrained the simulated occupant's pelvis relative to the seat but did not restrain the upper torso. Due to the unrestrained movement of the upper torso, impact forces were concentrated on small areas of the upper body, such as the head. These concentrated forces resulted in a predicted high risk of head injury. In the lap/shoulder belt-restrained simulation, for the occupants seated on the side of the bus opposite the third impact, the simulated occupant's upper torso was predicted to slide laterally out of the shoulder harness. The resulting simulated occupant motion was similar to that seen in the lap belt-restrained condition. In the unrestrained condition, impact forces were distributed over a large portion of the simulated occupant's body. The distribution of impact forces resulted in a reduced risk of head injuries. Similar findings were noted for the Holmdel, New Jersey, accident. Thus, the potential exists for an increased risk of injury to occupants restrained using typical seat belt designs. However, because injuries occurred for all restraint conditions in the simulated accidents and because injury levels varied depending upon occupant kinematics and seating location, the Safety Board concludes that it cannot be determined whether the current design of available restraint systems for large school buses would have reduced the risk of injury to the school bus passengers in these accidents. Even though the Safety Board was unable to determine whether current restraint systems would have decreased injury levels in these accidents, potential crash protection systems that would better protect occupants are possible. For example, in the Holmdel simulation, the reduced head injuries seen for the simulated occupants seated on the opposite side of the bus from the impact and

[30] These simulated occupants were seated in the same locations as the actual passengers who sustained head injuries in the actual accident.

restrained in lap/shoulder belts indicate that injuries could possibly be decreased with some form of restraint system. Therefore, the Safety Board further concludes that the potential exists for an occupant crash protection system to be developed that would protect school bus passengers in most accident scenarios. The Safety Board believes that once pertinent standards have been developed for school bus occupant protection systems, NHTSA should require newly manufactured school buses to have an occupant crash protection system that meets the newly developed performance standards and retains passengers, including those in child safety restraint systems,[31] within the seating compartment throughout the accident sequence for all accident scenarios.

[31] Any device (except a passenger system lap seat belt or lap/shoulder belt) designed for use in a motor vehicle to restrain, seat, or position a child who weighs less than 50 pounds.

Motorcoach Crashworthiness Issues

In the course of investigating three recent, severe motorcoach accidents,[32] the Safety Board became concerned that motorcoach passengers are not adequately protected in collisions. Although Federal Motor Vehicle Safety Standards (FMVSS) exist for large school buses relating to passenger seating, crash protection, and body joint strength, no similar standards apply to other types of large buses, including motorcoaches. In other words, no Federal regulation or standard requires that large buses sold or operated in the United States be equipped with active or passive occupant protection (other than for the driver).

From 1968 through 1973, the Safety Board issued 11 recommendations[33] to the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), or both, concerning restraints, including requiring that seat belts be installed in buses. These recommendations have not been implemented by either NHTSA or the FHWA, who have cited reasons such as:

- Seat belts would be impractical because buses are not designed for their use and cannot withstand floor loadings;
- The small number of deaths or injuries in bus accidents do not justify the installation of restraints;
- Tests conducted by the Bureau of Motor Carrier Safety (BMCS)[34] indicate that belts would be used by only a small percentage of passengers;
- New FMVSS relating to bus emergency exits, window retention and release, improved seating, and crash protection in new buses would be more effective, less costly, and more easily accepted by the public.[35.]

The last recommendation made by the Safety Board regarding occupant restraints in motorcoaches (Safety Recommendation H-73-42) was placed in a "Closed—Reconsidered" status on June 29, 1988, with a provision that the Safety Board continue to monitor motorcoach accidents to determine whether the installation and use of occupant restraints would mitigate injuries. Since this time, the Safety Board has continued to investigate motorcoach accidents in which passengers sustained serious injuries and fatalities from ejections and rollovers.

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[32] Accident No. HWY-98-MH-033, Burnt Cabins, Pennsylvania, June 20, 1998; Accident No. HWY-99-MH-007, Old Bridge, New Jersey, December 24, 1998; and Accident No. HWY-99-MH-017, New Orleans, Louisiana, May 5, 1999.

[33] These recommendations (H-68-18; H-70-4; H-71-10 and -11, H-71-34, -35, and -87; and H-73-1, -7, -18, and -42) are summarized in appendix E.

[34] Predecessor of the Office of Motor Carrier and Highway Safety.

[35] FHWA letter dated February 11, 1974.

In light of concerns raised about passenger safety by the current accident investigations, the Safety Board initiated this special investigation to reexamine the issue of seat belts in motorcoaches. In addition, more information and crash test data have become available on seat belts, specifically seat belts on motorcoaches. Much of this research has been conducted in Australia[36] and in the European Union (EU),[37] where passenger seat belts are now mandatory on motorcoaches.[38] In the United States, no full-scale crash testing of a motorcoach has been conducted since 1965.

Active Occupant Crash Protection

The Safety Board has long been interested in the issue of occupant restraints on motorcoaches. Appendix E summarizes this history with a table containing applicable Safety Board recommendations, including their status and NHTSA's and the FHWA's responses to them. Many of the reasons given for not requiring that restraints be installed on motorcoaches are no longer valid. In addition, many of the alternative measures promised were not carried through.

As an example, one of NHTSA's responses (March 21, 1973) to Safety Recommendation H-73-1 to incorporate seat belts on motorcoaches stated:

> With regard to the recommendation to provide seat belts for all passengers on intercity buses, you may be interested in the recent Notice of Proposed Rulemaking *Bus Passenger Seating and Crash Protection* printed…February 22, 1973. The National Highway Traffic Safety Administration in this proposal would require bus passenger seats which are stronger and safer and which afford greater protection to bus passengers. The standard as proposed would apply to buses of all types manufactured after September 1, 1974.

However, when the second notice of proposed rulemaking (NPRM) was issued on July 30, 1974, *only large school buses* were included in the proposed requirements. NHTSA determined that seating requirements for intercity and transit buses were not justified based upon cost-benefit studies.

On May 2, 1979, the FHWA advised the Safety Board that a 1963 study by the American Bus Association (ABA) and the FHWA's BMCS indicated that only 42 percent of passengers on a test trip used available lap belts during a portion of the trip, while only 25 percent used their available belts for the entire trip. The Administrator further advised

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[36] Lap/shoulder belts have been required on newly manufactured motorcoaches since 1994 in accordance with Australian Design Standard No. 68.

[37] EU member states (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom) require either lap belts (two-point belts) and an energy-absorbing seat or lap/shoulder belts (three-point belts). The seat belt directive that became effective October 1, 1997, specifies that a Member state can require motorcoaches to meet national legislation on seat belts. However, the directive further specifies that unless the vehicle is a new design, it does not have to meet the legislation's requirements until October 1, 1999, and that a Member state can set different standards until that date.

[38] For more information on European and Australian legislation and initiatives, see appendix D.

that a 1973 study by the ABA and the BMCS indicated that only 7.2 percent of the passengers had used available lap belts during a test trip. Yet, the FHWA decided to reconsider requiring lap belts in certain passenger positions (first two rows) if a cost-benefit analysis showed it would be beneficial. The Administrator informed the Safety Board that an NPRM would be published soliciting comments and information on requiring lap belts at specific seats in buses.

On May 31, 1979, a copy of a draft NPRM was furnished to the Safety Board, and on June 7, 1979, the FHWA's Associate Administrator for Safety sent a letter noting that "we are planning to issue a notice in the *Federal Register* asking for comments on the merit of initiating rulemaking to require lap safety belts at selected locations (in buses)." However, this notice was never published.

The latest NHTSA data estimate that, in 1997, the seat belt usage rate in the United States was 69 percent, a significant increase from the 1963 and 1973 studies cited by the FHWA. This increase indicates that the argument that the public is not in the habit of using seat belts can no longer be used as a reason for not equipping motorcoaches with restraints.

Safety Board-Investigated Accidents

Thirty-six motorcoach accidents investigated by the Safety Board from 1968 through 1997 are summarized in appendix F. These 36 motorcoach accidents resulted in 168 occupant fatalities. One accident, which involved fire in the passenger compartment (case 1), resulted in 19 occupant fatalities. Of the remaining 149 occupant fatalities, 106 occurred in accidents involving a rollover. Of these 106 fatally injured passengers, 64 were ejected from the motorcoach.

In 8 of the 36 accidents (cases 2 through 8 and 13), the Safety Board concluded that passenger restraints would have reduced or prevented injuries or fatalities. Of those eight accidents, seven involved a rollover. All of these accidents occurred before June 1988, when the Board classified the most recent restraint recommendation, H-73-42, "Closed—Reconsidered," based upon findings from the Safety Board accident investigations up to that point.[39] Sixteen motorcoach accidents were investigated after this recommendation was closed. Twelve of these accidents involved a rollover and resulted in 22 fatalities, 16 of which were ejections. In the four remaining accidents, which did not involve a rollover, five of the six fatally injured passengers were ejected.

Occupant Kinematics in Motorcoach Rollovers

The injury mechanisms in rollovers are similar to other types of collisions in that the injury severity is related to how fast the occupant is moving and how quickly the occupant stops. The injury tolerance level of an individual (which is based on age, health,

[39] The Safety Board found in accidents involving front and rear collisions (as opposed to rollovers) that restraints generally did not lessen injury outcome for passengers who sustained minor to moderate injuries and that their effect could not conclusively be predicted for more seriously injured passengers. The Safety Board noted that it would continue to monitor rollover accidents for the potential benefits of restraints.

and bone density) is also a factor, as are (1) the orientation of the occupant’s body at impact; (2) the distance over which the occupant decelerates; and (3) the objects struck by the occupant within the vehicle.

The occupant’s orientation at impact is important because the human body’s tolerance to impact varies. For example, the orientation of the head relative to the body at impact may greatly increase the chances of neck injury.

The second factor is the proximity of the occupant to the portion of the vehicle experiencing the high velocity change. For instance, if an occupant’s head is against the roof rail as its strikes the ground, the occupant’s head undergoes the same acceleration as the roof rail does as it strikes the ground. However, another occupant in the same bus who is tumbling about the interior cabin and is not in contact with any portion of the vehicle may not experience the forces associated with the roof’s impact with the ground.

In addition to hazards inside the vehicle, occupants in a rollover risk being ejected. When ejected from the relative safety of the vehicle interior, the occupant risks being struck by that vehicle or another vehicle on the roadway.

Occupant Kinematics in Motorcoach Ejections

The injury mechanisms of a passenger who is ejected are similar to those of a passenger who is tumbling about the interior. Again, the orientation of the passenger when striking the ground outside is an important factor. A passenger who remains in the vehicle will strike the interior surfaces at a velocity relative to the interior of the vehicle. An ejected passenger will strike the ground at a velocity relative to the ground. For instance, if a bus that is traveling at 60 mph collides with a vehicle and is slowed to 50 mph by the impact, the maximum velocity at which a passenger can strike interior surfaces is 10 mph. Yet, a passenger who is ejected from the vehicle can strike the ground at a relative velocity of 60 mph (assuming nothing slowed the passenger during ejection). Furthermore, passengers who are ejected risk being struck by the bus or another vehicle or other harmful objects.

Based upon the Safety Board’s investigations of motorcoach accidents and based upon the dynamics of rollovers and occupant ejection, the Safety Board concludes that one of the primary causes 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. Thus, the Safety Board concludes that the overall injury risk to occupants in motorcoach accidents involving rollover and ejection may be reduced significantly by retaining the occupant in the seating compartment throughout the collision. The Safety Board therefore believes once pertinent standards have been developed for motorcoach occupant protection systems, that NHTSA should 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.

Seat Belts

Seat belts are a common method of restraining occupants in their seats during an accident. However, motorcoaches in the United States are not required to be equipped with seat belts, and few are. Only 2 of the 36 motorcoach accidents that the Safety Board investigated involved motorcoaches equipped with passenger seat belts. In both cases, restraints were available only in the front-row passenger positions. (See cases 26 and 36 in appendix F.) In both cases, the passengers were not wearing the available restraints.

Seat Belts on Motorcoaches in the EU. As was noted earlier, the EU enacted legislation in June 1996 requiring that new motorcoaches be fitted with seat belts at all passenger positions. The primary intent of this legislation was to reduce fatalities due to ejection.

The lap belts installed on the European-style buses[40] are attached to the seat. Because of this, the ultimate ability of the seat/restraint system to retain the occupants is determined by the strength of the seat, the restraint system, and strength of the seat anchorages. The minimum seat anchorage system strength required for seats with integrated restraints in the EU is less than that required for U.S. automobiles. According to researchers who assisted in the development of the EU regulation, this lower limit was established based upon the UNECER80 crash pulse.[41] This crash pulse was chosen because it appeared to be a reasonable criterion, given a motorcoach's size and structure. In the EU, researchers believed that the crash pulse in a motorcoach is less than in an automobile, thus the seat anchorage strength could be less.

The EU conducted no dynamic crash testing of buses in support of its occupant restraint system design. Further, no dynamic crash testing of buses is required of manufacturers by the legislation. Although a researcher stated that the crash pulse was thought to be supported by dynamic crash testing of motorcoaches, no one was able to refer to actual crash tests. Sled testing was performed in support of this regulation at the Cranfield Impact Centre[42] using the UNECER80 crash pulse.

The lap belt was used because researchers at the Cranfield Impact Centre, which helped develop the EU requirements, thought it would be too difficult and not cost-effective to have a seat that was both energy absorbing and equipped with lap/shoulder belts. Since the regulation was developed, Cranfield Impact Centre researchers have developed a seat that is energy absorbing, incorporates lap/shoulder belts, is cost effective, and tests well when subjected to a UNECER80 crash pulse.

[40] A European motorcoach is typically equipped with one rear axle, a floor-level emergency door on the right side, a roof-mounted air conditioner unit, and tempered side windows.

[41] United Nations/Economic Commission of Europe (UNECE) Regulation (UNECER) 80 specifies anchorage strength for motorcoaches. UNECE requirements can be adopted by any United Nations member state but are not mandatory. The UNECER80 crash pulse refers to the specifications for sled decelerations defined in UNECER80, which allow for a range of decelerations over a given time.

[42] The Cranfield Impact Centre is a consulting company owned by Cranfield University, located near Bedford, England.

Seat Belts on Motorcoaches in Australia. In 1992, the Australian Government enacted legislation requiring lap/shoulder belts at all passenger positions for motorcoaches manufactured since 1994. Initially, Australia had intended to adopt an anchorage standard similar to the EU's. However, upon learning that the Stratos Seat Company had developed a seat that tested well when subjected to a crash pulse deceleration approximately twice the European requirement, that incorporated lap/shoulder belts, that could withstand an impact from behind by unbelted occupants (not an EU requirement), and that could be installed in motorcoaches at an affordable price, the Australians revised the standard to incorporate these conditions. Like the EU, Australia conducted no dynamic crash testing of motorcoaches in support of its regulation.

An accident involving a motorcoach equipped with the new restraint system occurred on January 7, 1997, in Tenterfield, Australia. This was a single-vehicle accident in which the motorcoach struck a culvert. The court report states that motorcoach was equipped with a Tripmaster computer (on-board vehicle recording system) that indicated the motorcoach was traveling 53 mph at impact and that no pre-impact braking occurred. According to the report filed by the principal engineer,[43] the motorcoach traveled 47.6 feet from the initial point of impact and sustained 3.3 feet of crush in the accident. Two passengers were fatally injured, both of whom were not restrained. One fatally injured passenger was walking down the aisle before the collision, and the other one was sleeping in the sleeping berth at the rear of the bus.

Global Harmonization. In June 1998, the United States became the first party in a UNECE agreement to establish harmonized global technical regulations for motorized vehicles. The purpose of the agreement is to determine the highest vehicle safety practices in the world against which to model the global regulations.

On January 5, 1999,[44] NHTSA solicited comments on its draft policy statement concerning priorities for implementing the 1998 agreement on the global technical regulations. This notice stated that, in May 1998, NHTSA had published a final rule

> reaffirming its policy of focusing its international harmonization activities on identifying those foreign vehicle safety standards that clearly reflect best practices, i.e., that require significantly higher levels of safety performance than the counterpart U.S. standard. NHTSA's policy is to upgrade its standards to the level of those foreign standards.

The Safety Board is convinced that this policy will result in safer motor vehicles in the United States and in other countries that participate in the UNECE agreement.

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[43] *Report on Inspection of MCA Bus From Tenterfield Crash*, Vehicle Standards R&D, Federal Office of Road Safety, Department of Transport and Regional Development, Canberra, Australia.

[44] Docket no. NHTSA-98-4956, notice 1, RIN 2127-AH29.

Lap Belts in Passenger Cars. A NHTSA study,[45] based on Fatality Analysis Reporting System (FARS) data from January 1988 through June 1997, examined the effectiveness of restraints at the rear seat outboard seating positions of passenger cars. According to the data, lap/shoulder belts are 77 percent effective in preventing fatalities in rollover accidents. This effectiveness does not come entirely from ejection reduction, since lap/shoulder belts are also 54 percent effective in reducing fatalities among passengers who remain in the vehicle during the rollover and are 28 percent effective in preventing passenger fatalities in frontal collisions.

The study also determined that lap belts at the rear outboard position in passengers cars are 76 percent effective in reducing fatalities in rollover accidents. However, lap belts were found to have an overall negative effect in frontal collisions, meaning that passengers in lap belts only are more likely to be fatally injured than those who are unbelted. These findings are consistent with earlier Safety Board findings[46] regarding lap belts that indicated that lap belts could have negative effects.

Motorcoach Crash Testing

Dynamic Rollover Crash Testing of Motorcoaches. A dynamic rollover test of a motorcoach was conducted in Germany in August 1995 by DEKRA,[47] a private-sector vehicle monitoring organization, using belted and unbelted 50th-percentile dummies. In the test, the dummies were placed in aisle side seats opposite the side of the bus that impacted the ground. The motorcoach was then dragged over a ramp at 40 kph (25 mph), causing it to roll onto its left side. The lap-belted dummies remained in their belts during the rollover and sustained lower head injury levels, as well as lower peak chest and pelvis decelerations, than the unbelted dummies. The test dummy that received the highest level of head injury was unbelted, and the predicted injury was the result of the dummy's head striking the luggage rack.

DEKRA's testing[48] also references two other rollover tests, one with a static overturn tested in compliance with UNECER66,[49] the other based on numerical simulations. Both of these tests support the contention that lap belts are beneficial on seats that turn upward as a result of being on the rising side of an overturning motorcoach.

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[45] NHTSA Technical Report, *Effectiveness of Lap/Shoulder Belts in the Back Outbound Seating Positions*, June 1999, DOT HS 808945.

[46] For further information, read Safety Study—*Performance of Lap Belts in 26 Frontal Crashes*, NTSB/SS-86/03, Washington, DC.

[47] *DEKRA* stands for Deutscher Kraftfahrzeug-Überwachungs Verein (loosely translated, "German Vehicle-Monitoring Association").

[48] Berg, F. Alexander, and Niewöhner, Walter, "Pointers Toward the Improvement of Safety in Buses, Derived From an Analysis of 371 Accidents Involving Buses in Germany and From Crash Test Results," Paper No. 98-S4-O-03 (DEKRA Automobile AG, Germany), *Proceedings of the 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*, Windsor, Ontario, Canada, May 31 through June 4, 1998, vol. 2, 791-806.

[49] UNECE Regulation 66 governs roof-strength requirements for motorcoaches.

The report's conclusions are less clear on the issue of lap/shoulder belts and cautions:

> The particular dynamic with side overturns and rollovers can lead to the torso of the belted passenger becoming free from the shoulder strap. This causes the entire belt to come loose and there is also a risk of passengers becoming released by the belt around the hips.

Concerns about lap belts were also raised. The report specifically states that for passengers seated on the side of the bus that impacts the ground during rollover, a lap belt alone cannot prevent the head, torso, arms, and hands of passengers from colliding with the rails or side windows. In addition, if the side structure breaks, the occupant's risk of striking the ground and sustaining severe injury are increased. However, the report cites research[50] indicating that passengers seated next to the window could be protected from partial ejection hazards by lap/shoulder belts that are properly tightened and fitted to prevent this occurrence.

Frontal Dynamic Crash Testing. Two dynamic frontal crash tests involving motorcoaches were performed by DEKRA. Both of the tests involved motorcoaches designed for the European market. The first test (conducted in November 1993) involved a motorcoach that struck the rear of a truck at approximately 25 mph; the second test (conducted in August 1994) involved a motorcoach that struck a fixed barrier at approximately 19 mph, with approximately 30 percent overlap. The peak deceleration in these tests was approximately 12 g and was of relatively short duration. During most of the impact duration, the deceleration was below 6 g. This report[51] stated:

> The flexibility of the front structure of the bus leads to relatively low levels of deceleration in the passenger area behind. This means belted and unbelted occupants are at relatively low risk of injury. Especially, when there is sufficient room in the front of the seat for the head and torso to move, lap belts can offer passengers protection in event of front collisions with the bus. If the back rest of the other seats are positioned in front of the passenger, it must be insured that no awkwardly positioned and designed component present a risk of injury.

Seat Belt Analysis

As was concluded earlier in this special investigation in the discussion on occupant kinematics in ejections and rollover, one of the primary causes 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. Further, injuries and fatalities may be reduced significantly in motorcoach collisions by retaining passengers in their seats throughout the collision.

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[50] Grösch, Lothar, Mattes, Bernhard, and Schramm, Dieter, "Smart Restraint Management and Comprehensive Concept," *Proceedings of the International Symposium on Sophisticated Car Occupant Safety Systems Airbag 2000*, Karlsruhe, Germany, November 26 through 27, 1996, pp. 16-1 through -20.

[51] Berg and Niewöhner, 791-806.

Australia and the EU now require seat belts on motorcoaches. The EU's regulation requires that motorcoaches be fitted with lap belts or lap/shoulder belts at each passenger position. Australia's regulation requires lap/shoulder belts at all passenger positions. Although crash testing was not performed in support of these regulations, a limited number of frontal and rollover motorcoach crash tests have been performed in Germany. The analysis of data available from these tests and sled testing performed at Cranfield Impact Centre raise concerns that the lap belts (two-point restraints) used in these tests could increase the potential for injury in frontal collisions for certain seat spacing or if the seatback in front of the occupant were incorrectly designed.

The lap/shoulder (three-point) occupant restraint system required in Australia and the one designed by the Cranfield Impact Centre demonstrate the ability to design lap/shoulder restraint systems for motorcoaches. NHTSA has stated in its global harmonization policy that it would identify the best international practices and upgrade to those standards. The Safety Board agrees with this principle and agrees that the most advanced technology should be utilized when designing new occupant restraint systems.

The EU and Australian occupant crash protection regulations were based on sled testing. Actual dynamic testing of motorcoaches was not conducted to determine the effectiveness of restraint systems as occupant protection systems.

Occupant protection systems should be tested to performance standards before their implementation to ensure that they are beneficial and to guard against possible negative effects such as have occurred in the rear seats of automobiles in frontal collisions. The Safety Board concludes that new occupant crash protection systems for motorcoaches should be tested to uniform performance standards developed by NHTSA that are based upon actual crash testing of motorcoaches to ensure occupant safety. The Safety Board believes that in 2 years, NHTSA should develop performance standards for motorcoach occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers.

Passive Occupant Crash Protection

Passive occupant protection refers to protective devices that require no action by the occupant to implement. Current passive safety features on automobiles include airbags and energy-absorbing materials on interior surfaces. Because these measures require no occupant action, they are appealing as the starting point of an occupant crash protection system. In the following sections, passive protection measures designed to reduce injuries of motorcoach passengers and to prevent passenger ejections are examined. These measures include window size and glazing and roof strength.

Window Glazing

On November 29, 1988, a chartered 1987 Motor Coach Industries (MCI) motorcoach was traveling southbound in the express lane of the New Jersey Garden State Parkway when it gradually veered to the right off the travel lane, sideswiped a guardrail, and skidded back onto the highway.[52] After returning to the highway, the motorcoach overturned onto its right side and slid approximately 220 feet across two express lanes before coming to rest.

The side windows of the motorcoach were made of abrasive-resistant, coated acrylic. During the overturn, the 27 passengers seated on the left side of the motorcoach were thrown from their seats and fell on top of the 22 passengers seated on the right side of the motorcoach. The passengers became entangled on the right side of the motorcoach as it slid across the highway before coming to rest. None of the passengers were ejected. The injuries sustained ranged from minor to severe and included fractured ribs, lacerations, abrasions, and contusions. Sixteen passengers were hospitalized. The driver stated he was not wearing the available lap belt and was partially ejected through the driver's side of the broken windshield.

The Safety Board determined that if the side windows had been equipped with the more commonly used tempered safety glass, they might have broken during the motorcoach overturn, subjecting the occupants to contact with the road surface. Because the acrylic windows did not break, they may have prevented occupants from contacting the road surface and sustaining more serious or even fatal injuries.

As a result of this investigation, the Safety Board issued Recommendation H-89-16 to the United Bus Owners of America (UBOA)[53] and the ABA. The recommendation requested that UBOA and the ABA advise their members of the potential safety benefits of the use of abrasion-resistant, coated acrylic windows in protecting bus occupants in overturns. Because these organizations responded by publishing the requested information in their organizations' newsletters, the Safety Board classified Safety Recommendation H-89-16 "Closed—Acceptable Action" on June 22, 1990, for the ABA, and on June 28, 1990, for UBOA.

Since 1993, NHTSA has conducted an ongoing research project concerning ejection mitigation, *Improved Glazing for Reducing Ejection.* The objectives of this research are to determine whether improved side window glazing in passenger cars, light trucks, and vans, would reduce the possibility of full or partial ejection and to determine whether such glazing should be regulated by NHTSA. A NHTSA status report[54] published in 1995 estimated that advanced glazing composed of glass and plastic could save 1,313 lives and prevent 1,297 serious injuries per year in passenger cars. Some of the glazing tested did increase the potential for head injuries as compared with tempered glass, which is currently used in most side windows of cars, trucks, and vans. In the report, NHTSA recommended continuing research by expanding the computer modeling and prototype testing. A second status report on the agency's ejection mitigation research is currently undergoing internal review.

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[52] For further information, read Highway Accident Summary Report—*Intercity-Type Buses Chartered for Service to Atlantic City, New Jersey*, HAR-89/01/SUM, Washington, DC.

[53] The United Bus Owners of America is now the United Motorcoach Association (UMA).

[54] *Ejection Mitigation Using Advanced Glazing*, Status Report, NHTSA, Washington, DC, November, 1995.

Some of the design limitations encountered when utilizing the glazing in automotive windows do not apply to motorcoach side windows. For instance, in an automobile, the side window glazing can be supported only on three sides. In addition, an automobile side window must withstand the constant use of being raised and lowered within the frame. In contrast, the side window glazing in a motorcoach remains stationary and can be bonded to the frame.

The DEKRA report[55] on motorcoach rollovers and restrained occupants raised concerns about lap belts. The report stated that lap belts may not prevent the head, torso, arms, and hands of passengers seated on the side of the bus that impacts the ground during rollover from colliding with the rails or side windows. In accidents where the side structure breaks, the occupant's risk of striking the ground and sustaining severe injury are increased. The Safety Board concludes that equipping motorcoach side windows with advanced glazing may decrease the number of ejections of unrestrained passengers during motorcoach accidents and decrease the risk of serious injuries to restrained passengers during motorcoach accidents. The Safety Board believes that NHTSA should expand its research on current advanced 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.

Motorcoach Roof Strength and Window Size

No FMVSS exist that either limit a window's maximum size in any type of bus (including school buses) or, except in the case of large school buses, address rollover strength in motorcoaches. In the 1970s, the Safety Board raised concerns about the relationship between increased window size and roof strength. This concern focused primarily upon the decrease in the number of vertical supports between windows or roof bows that accompanied the increase in window size.

Passenger-Side Window Size. Buses manufactured after September 1, 1973, are required to comply with the FMVSS 217 (49 *Code of Federal Regulations* [CFR] 571.217) requirement that emergency exits on buses have an opening large enough for unobstructed passage.[56] Although FMVSS 217 contains requirements for minimum bus emergency exit size and for window retention and release, no *maximum* window size is specified.

Safety Board staff measured the passenger windows of motorcoaches manufactured by Thomas Built, Dina, MCI, Van Hool, Setra, and Prevost to determine the current average size of motorcoach passenger windows.[57] Staff found that the average window area is 2,040 square inches,[58] indicating that the "average" motorcoach side

[55] Berg and Niewöhner, 791-806.

[56] An ellipse having a major axis of 19.68 inches and a minor axis of 12.99 inches, or a computed area of 200.8 square inches.

[57] To account for differences in securing methods, as well as for varying frame dimensions, only the horizontal and vertical dimensions of the transparent glazing itself were measured. This method simulates the opening size created if the glazing were completely broken out while the window frame remained attached to the motorcoach body.

window is 10 times larger than is required to meet the emergency exit standard under FMVSS 217. The size difference does not include allowances for framing and/or gaskets in the motorcoach windows. In addition, the size of the opening would increase if the window framing or gasket were ejected or if the window were an emergency exit and came open during a rollover.

Roof-Strength Issues. On October 10, 1971, a 1970 MCI motorcoach was traveling westbound on U.S. 66 near Marshfield, Missouri, when it collided with the left side of a station wagon in the westbound lanes of the four-lane, divided highway.[59] After impact, the motorcoach rotated clockwise (as seen from above) and skidded approximately 150 feet, left the pavement, and crossed the shoulder. It then vaulted into a drainage ditch, rolled 1 ¼ times, and came to rest on its left side. Four passengers were fatally injured, including one of five passengers ejected through the side windows. A collapsed roof crushed two passengers. The remaining 33 passengers and the driver sustained moderate to severe injuries.

For that accident, the Safety Board determined that the availability and use of seat belts or another form of restraint by the passengers would have reduced the numbers of injuries and fatalities. In addition, the investigation determined that during the rollover, gross downward and sideward deflection of the roof occurred and the roof support design caused the side-window posts to fail due to concentrated loads. The Safety Board concluded that the strength of the roof support structure for "picture-window" type buses are inadequate.

As a result of the investigation, the Safety Board recommended that newly constructed interstate-type buses be equipped with approved occupant restraints (Safety Recommendation H-73-1) and made two additional recommendations in 1973 regarding rollover strength and window size:

> H-73-3
>
> The Bureau of Motor Carrier Safety (BMCS), Federal Highway Administration, review intercity bus design and the types of damage suffered in rollover accidents in an attempt to determine whether structural strength in the window areas may have been reduced in recent years in buses having very large side windows; and that BMCS prepare a rollover performance test, or other performance tests, for buses which can reveal the structural strength of buses in the areas stressed by rollover.
>
> H-73-4
>
> The manufacturers of intercity buses review their existing designs of buses having very large side windows to determine whether it is technically feasible to prevent critical localized structural failures and to increase the general strength of the

[58] The average window width is 60 inches, and the average window height is 34 inches.

[59] For additional information, read Highway Accident Report—*Bus/Station Wagon Collision Followed by Bus Overturn, U.S. Route 66, Near Marshfield, Missouri, October 10, 1971*, NTSB-HAR-73-1, Washington, DC.

> window area of buses: by the use of greater-strength window columns; by employing a larger number of continuous structural members through the window area; and by using smaller windows.

In its March 23, 1973, letter responding to these recommendations, the FHWA stated that the BMCS had no funds to perform the rollover testing suggested by Safety Recommendation H-73-3, noting “Such tests have merit and will be considered for future research funding requests.” Regarding Safety Recommendation 73-4, the FHWA stated “…we concur in the thrust of this recommendation. We shall undertake a review of our window glazing requirements to determine if the matter should be set for rulemaking.” Consequently, the Safety Board classified Safety Recommendations H-73-3 and -4 “Closed—Acceptable Action” on January 1, 1980. As was mentioned earlier in this section, NHTSA has been performing research since 1993 on window glazing for passenger cars and light trucks, the method of improving window strength cited by the FHWA in its 1973 response to Safety Recommendation H-73-4. However, almost 20 years after Safety Recommendations H-73-3 and -4 were closed, rollover testing on motorcoaches has yet to be performed.

The EU has proposed legislation, based on UNECER 66, concerning the rollover strength of buses and motorcoaches. The European Commission (the Commission) believes that a directive on rollover strength in the bus construction standards is essential for ensuring the effectiveness of the seat belt legislation. The Commission also believes that mandating seat belts without a rollover strength requirement exposes passengers to potential injuries if the roof crushes downward and decreases the available occupant space, as would occur during a 180-degree or greater rollovers. At present, only the United Kingdom and Spain require mandatory compliance with the Commission’s rollover strength requirements.

As was noted in the preceding section on window size, the size of passenger windows continues to increase. As window size increases, the number of vertical supports between windows decreases. Thus, in a rollover accident, fewer vertical supports must carry a larger load. The Safety Board concludes that because the increased size of passenger windows in motorcoaches may affect roof strength, rollover strength standards must be developed to take into account the effect of typical window dimensions. Therefore, the Safety Board believes that in 2 years, NHTSA should develop 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. The Safety Board also believes that once performance standards have been developed for motorcoach roof strength, NHTSA should require newly manufactured motorcoaches to meet those standards.

Bus Classification and Data Collection

The vehicle definitions within the National Highway Traffic Safety Administration's (NHTSA's) Federal Motor Vehicle Safety Standards (FMVSS)[60] are important because the applicability of safety standards relating to occupant crash protection is based on these definitions. Vehicle classification within Federal accident databases is important because public policy on vehicle safety is based, in part, on the analysis of these databases, especially NHTSA's Fatality Analysis Reporting System (FARS).[61] NHTSA does not have separate definitions for different bus body types in the FMVSS other than to define them as either a bus or a school bus. In contrast, NHTSA uses five body type classifications in FARS for buses: intercity/cross country bus, school bus, transit bus, other bus, and unknown bus. This section discusses how these definitions and classifications affect the collection, coding, and accuracy of bus accident data. It also considers the role of on-board recorders in gathering accident data.

Bus Definitions in the FMVSS

The FMVSS define a bus as a motor vehicle with motive power, except a trailer, designed for carrying more than 10 persons. They define a school bus as a bus sold or introduced in interstate commerce for purposes that include carrying students to and from school or school-related events. The definition does not include a bus designed and sold for operation as a common carrier in urban transportation. A school bus is the only vehicle in the FMVSS that is defined by use; all other motor vehicles are defined by body type. In other words, according to the FMVSS, a bus is either a school bus or some other type of bus that is not further defined.

The body types that are not further defined in the FMVSS include what are commonly referred to in the industry as motorcoach/intercity buses and transit/urban buses.[62] Also included are what the Safety Board, in this special investigation, calls specialty buses. Examples of specialty buses include those that retain their originally manufactured cabs and chassis and that are later equipped with an after-market specially manufactured passenger body, as well as those that appear similar to motorcoaches but

[60] The purpose of the FMVSS is to a) reduce the risk of a vehicle crash by specifying minimum performance levels for brakes, lights, and other components and to b) reduce the risk of injury, should a crash occur, by specifying minimum requirements for vehicle performance in crashes, as related to occupant protection, for occupant restraints, roof and body joint strength, fuel system integrity, child safety systems, and other areas.

[61] FARS was established in 1975 and contains data on fatal traffic crashes in the 50 States, the District of Colombia, and Puerto Rico. To be included in FARS, a crash must involve a motor vehicle traveling on a road open to the public and result in the death of a person within 30 days of the crash.

[62] A transit bus as defined in this report is a vehicle that frequently loads and unloads passengers and operates primarily in local, scheduled route service at lower-than-highway speeds. These buses are manufactured with space and accommodations, such as support bars or straps to use as hand-holds, for standing passengers.

have a lower chassis and no lower luggage compartment. In addition, vehicles that can carry more than 10 passengers, which the public commonly refers to as vans, are built to bus standards and thus are actually buses. (For examples of buses built to school bus standards and of buses with undefined body types built to FMVSS bus standards, see figures 24 and 25.)

The Federal Motor Carrier Safety Regulations (FMCSR)[63] define a bus in two ways: as any motor vehicle, including taxicabs, designed, constructed, or used for the transportation of passengers (49 *Code of Federal Regulations* [CFR] 390.5) and as a vehicle designed to carry more than 15 passengers, including the driver (49 CFR 393.5). Thus, two Federal agencies (NHTSA and the Federal Highway Administration [FHWA]) in the U.S. Department of Transportation (DOT) have three different definitions of a bus and also differ as to the minimum number of passenger seats in a motor vehicle defined as a bus. With the exception of a school bus, the classifications used by NHTSA for the FARS database are not consistent with any of these definitions. The Safety Board therefore concludes that the DOT does not have standard definitions or classifications for the various bus types.

Data Collection

To determine the crashworthiness of motorcoaches and the magnitude of the problem of occupant ejection, the Safety Board reviewed 40 bus accidents that it had investigated between 1968 and 1997. (For further information on these accidents, see appendix F.) Investigators examined these accidents in conjunction with FARS data to identify the role of occupant ejection in fatalities and injuries in all fatal motorcoach accidents. Of the 40 bus accidents reviewed, 27 had occurred since 1975, when FARS was established, and the information from those 27 accidents was compared to that in the FARS database. The purpose of this comparison was to obtain some indication of the accuracy and completeness of the data in FARS and, therefore, its suitability for use in determining the extent of occupant ejection in motorcoach accidents. Five accidents[64] involving vehicles that were manufactured as school buses, but not operated as school buses[65] at the time of the accident, were also selected for comparison.

In 1993, in addition to the five body type classifications for buses in the FARS database, NHTSA made provisions for identifying van-based school buses and transit buses. Based on FARS classifications, the appropriate body type for all the motorcoach accidents selected should have been *intercity/cross country bus*. Nonetheless, investigators requested data for all five body types because specific Safety Board accidents could not be located in FARS by this body type using the available definition or coding instructions.

[63] The Federal Motor Carrier Safety Regulations, administered by the FHWA, apply to commercial motor vehicles in interstate commerce.

[64] Crashes involving school bus-type vehicles occurring at or near Tifton, Georgia, April 11, 1987, NTSB No. HAR-79/02; Devers, Texas, December 23, 1983, NTSB No. HAR-84/06; Wofford Heights, California, July 7, 1984, NTSB No. HAR-85/01; Carrollton, Kentucky, May 14, 1988, NTSB No. HAR-89/01; and Palm Springs, California, July 31, 1991, NTSB No. HAR-93/01.

[65] As defined by NHTSA in the FMVSS.

Figure 24. Vehicles built to school bus standards (coded in FARS as school buses)

Bus Coded in FARS as Unknown or Other

Bus Coded in FARS as a Van-Based Bus

Figure 25. Vehicles built to bus FMVSS

Bus Coded in FARS as a Motorcoach/Intercity Bus

Bus Coded in FARS as Unknown or Other

Figure 25. Vehicles built to bus FMVSS

For example, the GMC motorcoach occupied by a church group in the Eureka Springs, Arkansas, accident (NTSB No. HAR-87/01/SUM) was coded as a *school bus*, and three of the five school bus body types were classified as *other bus*.[66] Discrepancies were also noted in the classification of ejected passengers who were fatally injured. For instance, the Safety Board investigated an accident involving a motorcoach that occurred near Vernon, New Jersey, and resulted in six fatalities of passengers who were ejected (NTSB/HAR-93/02). For this accident, FARS coded the body type of the motorcoach as *unknown* and the six fatalities as *unknown if ejected*.

Table 9 presents the results of a comparison of Safety Board and FARS reporting on fatalities and fatal ejections by body type. For the 32 accidents shown in this table, the Safety Board and FARS reported different numbers of accidents for each body type. In addition, FARS identified 14 fewer fatal ejections for all body types combined than the Safety Board. In the motorcoach category, FARS identified 34 fewer fatal occupant ejections than the Safety Board. Given such discrepancies in data, the Safety Board concludes that FARS is not a reliable source for identifying the number of fatal occupant ejections in motorcoaches.

Table 9. Fatalities/fatal occupant ejection by body type

Body Type	No. Accidents		Fatalities		Fatal Ejection	
	Safety Board	FARS	Safety Board	FARS	Safety Board	FARS
Motorcoach	24	12	134	46	54	20
School Bus	5	3	45	34	8	5
Transit Bus	1	3	1	19	0	2
Other Bus	2	11	7	82	1	20
Unknown Bus	0	3	0	6	0	2
Total	**32**	**32**	**187**	**187**	**63**	**49**

The Safety Board is also concerned that data may be incomplete for the other bus classifications. For example, the FMVSS classify a 15-passenger van as a bus, but FARS places it in the van-based light trucks category. Thus, NHTSA's FMVSS and its FARS are not consistent in identifying a bus. The varying body styles of specialty buses further contribute to difficulties in accurate bus classifications.

During the Safety Board's Bus Crashworthiness Public Hearing, a representative from NHTSA stated that the agency is concerned about the classification of buses under FARS, which the representative attributed to the variety of bus types used in the United States. He specifically referred to the classification of "chopped" vans and the approximately 20 percent of buses categorized as *unknown bus*. NHTSA reported that it is working with the bus industry to develop a better classification system for buses that will incorporate the classification into the vehicle identification number (VIN). NHTSA has

[66] School bus body types involved in the Devers, Wofford Heights, and Palm Springs accidents.

the authority to specify a character and incorporate it into the VIN, but according to the NHTSA representative, modifications would take years. Therefore, NHTSA prefers that the manufacturers voluntarily incorporate the change to the VIN.

Safety Board staff met with NHTSA representatives to discuss their concerns about the Safety Board's findings. NHTSA acknowledged that bus classification data in FARS are incomplete, noting that source documents used to code FARS data do not provide specific details about the bus body type. According to NHTSA, the agency is working with the manufacturers to identify bus make, model, and body type, using the VIN, particularly buses that have previously been coded as either *unknown* or *other bus*. NHTSA is also expanding the *special use* category to identify how a bus is being used. For instance, if a motorcoach is used to transport pupils for a school function, it will be coded as an *intercity bus with special use as a school bus*.

The Safety Board concludes that the incorporation of bus identification into the VIN and the expansion of the use category will correct some of the inaccuracies in FARS data, but without standard definitions and accurate classification of buses within FARS, incomplete data and inaccuracies will still exist.

Therefore, the Safety Board believes that in 1 year and in cooperation with the bus manufacturers, the DOT should 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.

NHTSA also indicated that source data collected by the States may be incomplete due to a lack of specificity on accident reporting forms and in vehicle registration files. For example, Alabama's accident reporting form defined a bus as "a motor vehicle providing seats for *16* or more persons including the driver and used primarily for the transportation of persons." New Mexico's form defines bus as a vehicle that has seats for more than *15* people (including the driver).

The Model Minimum Uniform Crash Criteria (MMUCC) were developed in 1998 with the cooperation of NHTSA, the FHWA, and the National Association of Governors' Highway Safety Representatives (NAGHSR). They developed the model in an attempt to address the disparate accident data being collected by the States and to provide requested Federal guidance to States that were revising their accident data reporting forms. One purpose of the model was to ensure that the States were collecting at least the minimum amount of information needed for FARS.

The MMUCC's definition of a bus, however, is different from other Federal definitions. The MMUCC's data collection requirement for an accident involving a bus includes an indication of whether the accident was school bus-related and whether the vehicle configuration was one of two bus types, that is, either a bus with seats for more than 15 people, including the driver, or a bus with seats for 7 to 15 people, including the driver. If States are being advised that these are the only bus data that need to be collected, then NHTSA may have difficulty accurately identifying the bus body type of an accident vehicle for use in the FARS database. The Safety Board concludes that the MMUCC do not provide specific enough guidance to the States on bus body type coding. Therefore, the Safety Board believes that once the standard definitions and classifications for each of the different bus types have been established in the FMVSS, the DOT, in cooperation with the NAGHSR, should amend the MMUCC's bus configuration coding to incorporate the FMVSS definitions and standards.

School Bus Occupant Injury Data

The accuracy of school bus injury data has been debated by the pupil transportation community. According to testimony from a NHTSA representative at the Safety Board's August 1998 public hearing on bus crashworthiness, the agency believes that the General Estimates System (GES)[67] is reliable for estimating injuries in passenger cars but that bus classification in the system is inaccurate. He also stated that NHTSA is focusing on this problem and believes that additional information on bus passenger injuries, such as injury levels, needs to be collected.

The National Safety Council (NSC)[68] recently announced that it will no longer estimate the number of school bus injuries during the year. An NSC representative informed Safety Board staff that injury estimates derived from information collected by the States are no longer possible. Problems arose because the States collect information in a nonstandard form,[69] and some States do not report at all. In addition, the policy in many school districts is to have all passengers automatically taken to the hospital when involved in an accident, regardless of whether they are injured. Consequently, some passengers are counted as injured, even when they go to the hospital only as a precaution. This policy, as well as the level of injury, should be considered when collecting and analyzing the data.

The Safety Board concludes that school bus accident injury data are incomplete, and, therefore, injuries cannot be reliably estimated. The Safety Board believes that NHTSA should modify its methodology to collect accurate, timely, and sufficient data on passenger injuries resulting from school bus accidents so that thorough assessments can be made relating to school bus safety.

On-Board Recording Devices

On-board recording devices represent an available technology that could be implemented to facilitate bus classification and data collection. On-board devices that record accident data, including crash pulses and other vehicle parameters, are now being used on highway vehicles in Europe. This recording technology has recently been introduced in the U.S. market and offers an effective means for NHTSA to gather crash

[67] Data for the GES come from a nationally representative sample of police-reported vehicle crashes of all types, from minor to fatal. NHTSA, using the GES, estimates that between 1988 and 1996, passengers in school bus accidents sustained approximately 8,500 injuries annually.

[68] The NSC is a not-for-profit public service organization that was chartered by an act of Congress to educate and influence society on matters of safety.

[69] The NSC's *Accident Facts*, an annual report, states that variations exist among the States in several areas, including operations, definitions of terms, and lack of comparable reporting.

pulse data on school buses and motorcoaches. By the end of 1999, an estimated 200 accident recorders will be installed on commercial vehicles in the United States.

Although devices that record accident data have only recently been introduced to the U.S. market, recording systems that provide fleet management information have been in use for several years. These systems often record minimal data such as vehicle speed exceedances and are used primarily for driver monitoring and training. Although capable of providing limited data for accident investigations, these recorders do not record the quantitative data necessary for a thorough and accurate reconstruction of an accident sequence. Secondary recording devices, such as engine control modules, have also provided data to investigations, but their value to investigations is also limited by the minimal information recorded and the format of the recorded information.

Off-the-shelf on-board vehicle recording systems have been in use in Europe for several years. These recorders have not only provided needed crash data and assisted in accident investigations, but have also helped to reduce accidents for vehicles equipped with recorders. For instance, in 1996, all 62 patrol cars of a Berlin, Germany, police office were equipped with accident data recorders. Subsequently, these vehicles experienced a 20-percent reduction in driver-related accidents and a 36-percent reduction in the number of accidents that occurred during emergency trips. As a result, the Berlin police authority equipped its entire fleet of more than 400 patrol cars with accident data recorders.[70]

Another study, published in 1995, which was conducted as part of the EU's safety assessment monitoring of vehicles with automatic recording devices, involved equipping 9 vehicle fleets, or 341 vehicles, in Great Britain, the Netherlands, and Belgium with accident data recorders. The 1-year program also included a control group, for a total of 850 vehicles. At year's end, the accident rate had decreased by 28.1 percent for those vehicles equipped with recorders, as compared with the control group. Accident data recorders have also been used on buses in other countries. During a trial period in Germany, where 123 buses in the Baden-Württemberg bus fleet were equipped with recorders, the number of accidents in that fleet decreased between 15 and 20 percent (depending on the company concerned), as compared to the reference period.[71]

On-board recorders have been used on highway vehicles for fleet management and operator oversight for several years in the U.S. In addition, recording formats such as tachographs that automatically record driver operational information on paper, have been in use for over two decades. For example, the Police Department of Metropolitan Nashville and Davidson County, Tennessee, has been using tachographs on its vehicles for approximately 20 years. Not only has it been a vital management tool, but the initial study performed for the police department showed that accident rates had dropped. The accident

[70] Lehmann, Gerhard, and Reynolds, Tony, "The Contribution of On-board Recording Systems to Road Safety and Accident Analysis," *Transportation Recording: 2000 and Beyond*, Proceedings, International Symposium on Transportation Recorders, May 3-5, 1999, Arlington, Virginia (Washington, DC: National Transportation Safety Board, and The Hague, Netherlands: International Transportation Safety Association) 243-5.

[71] Lehmann and Reynolds, 243-5.

rate for the Traffic Section dropped from 1.3 to 0.6 accidents per 100,00 miles, while the accident rate for personal injury accidents in the Patrol Section experienced a 55-percent reduction to 0.25 accidents per 100,000 miles.[72]

On-board recorders have been commonly used as many as 6 years by more than 100 U.S. jurisdictions to manage their school bus fleets. The jurisdictions using fleet management or trip recorders include Montgomery County, Maryland; Washington County, Maryland; Los Angeles, California; Cherryvalley-Springfield, New York; Dryden, New York; Guilderland, New York; and Newark, New York. As was discussed earlier in this section, European and U.S. studies have found the use of both accident and fleet management recorders has had a positive impact on operational safety for other types of vehicle fleets. A study[73] commissioned by Laidlaw, Inc.,[74] found safety benefits for school bus fleets as well. Prompted by the comparatively high accident rate in a school bus fleet in Bridgeport, Connecticut, the Laidlaw study examined the effect on safety following installation of fleet management on-board recorders. The study, which took place from December 1, 1996, to May 30, 1997, consisted of fitting 65 of the 150 school buses in the Bridgeport fleet with fleet management recorders. During the study, driver speeding was monitored, and those drivers who spent over 25 percent of their trip miles at speeds over a set threshold were required to participate in counseling sessions. At the end of the trial period, those buses not equipped with on-board recording systems accounted for 72 percent of the fleet's accidents.[75] In light of these results, Laidlaw installed on-board fleet management recorders in the remainder of the Bridgeport fleet. After a year, officials were able to identify a contributing factor to the high accident rate that related to driver training. Laidlaw subsequently evaluated and accordingly modified its training program.

Although the fleet management recorders used in this study and in other U.S. school bus fleets do not provide data such as crash pulses, the combination of fleet management information and limited data, such as speed, made improvements in safety possible for Laidlaw's Bridgeport fleet. Further, the presence of on-board recorders for fleet management in more than 100 school bus fleets shows that many jurisdictions are already taking advantage of the tools that on-board recorder systems can provide. Because of the safety improvements that have occurred as a result of using on-board recorders, both for accident data and fleet management, the Safety Board concludes that the use of on-board recorders may help reduce the accident rates of vehicle fleets.

On-board recorders can also provide important crash pulse data and other vehicle information during frontal impacts, side impacts, rollovers, and other dynamic vehicle events. To date, much of the debate regarding bus occupant protection has been fueled by the lack of available crash pulse data. On-board recorders constitute the most thorough method of obtaining bus accident data; moreover, the collection of crash data will be

[72] Gill, Captain Paul J., and Larson, Lynn D., *A Report on the Use of Tachographs in Marked Police Vehicles*, Police Department of Metropolitan Nashville and Davidson County, Tennessee, 1979.

[73] *Final Report for Bridgeport, CT Facility*, ARGO Fleet Systems, VDO North America LLC, June 12, 1997.

[74] Laidlaw, Inc., is the largest contract operator of school bus fleets in the United States.

[75] ARGO Fleet Systems *Bridgeport* report, 1997.

necessary for the continuing development of bus occupant protection systems. Because of these factors, the Safety Board concludes that on-board recorders are needed to provide quantitative data to evaluate the dynamics of bus crashes. The Safety Board is of the opinion that to enhance the accuracy of school bus and motorcoach investigations, parameters in addition to crash pulse or acceleration data, such as vehicle speed, engine speed, heading, and the status of different lights and vehicle systems, are needed. Further, the parameters should be recorded at a sampling rate that is sufficient to define vehicle dynamics. In addition, the resulting data should be preserved in the event of a vehicle crash or an electrical power loss. The Safety Board therefore believes that NHTSA should 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, 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.

Through years of experience with on-board recording devices in the aviation, rail, and marine modes of transportation, the Safety Board and the transportation industry have learned a great deal about the effective introduction of recording technology. Establishing industry standards for recording in these modes has been critical to effective implementation of on-board recorders. Industry standards ensure consistency in recorded data and prevent the proliferation of multiple formats and configurations. They also foster the efficient introduction of new recording system technology.

The factors identified in developing on-board recording standards for other modes of transportation provide a basis for formulating highway recording standards. Parameters to be recorded, data sampling rates, duration of recording, interface configurations, and data storage format all need to be considered. Other factors include survivability issues, such as fluid immersion, impact shock, crush penetration, and fire. Following recent advances in technology, independent power supplies are being introduced into the on-board recorder industry. Use of an independent power supply helps prevent the loss of recorded data when main vehicle power ceases and results in loss of power to the recorder. An additional factor to be considered is the incorporation of fleet management tools discussed above. Finally, a critical factor in the development of effective recording standards is the ability to accommodate future requirements and technological advances.

Applying the knowledge gained during implementation of on-board recorders in other transportation modes is an important step to the effective implementation and use of on-board recorders on highway vehicles. The benefits of industry standards for on-board recorders in other modes of transportation demonstrate the need for similar standards in the highway industry. The Safety Board concludes that establishing on-board recording standards for highway vehicles will provide a necessary foundation for the future use of on-board recorders. The Safety Board believes that NHTSA should 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, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances.

Conclusions

1. In the accidents analyzed for this special investigation, school bus passengers who remained within the seating compartment but not within the intrusion area during the accident sequence were less likely to have been seriously injured than passengers who were out of the compartment before the collision or who were propelled from the compartment during the collision.

2. Because of compartmentalization, school bus passengers are safer now than they were before 1977.

3. Current compartmentalization is incomplete in that it does not protect school bus passengers during lateral impacts with vehicles of large mass and in rollovers, because in such accidents, passengers do not always remain completely within the seating compartment.

4. All potential designs for occupant protection systems to be used on school buses should be tested to uniform performance standards developed by the National Highway Traffic Safety Administration to ensure occupant safety.

5. It cannot be determined whether the current design of available restraint systems for large school buses would have reduced the risk of injury to the school bus passengers in the accidents analyzed for this special investigation.

6. The potential exists for an occupant crash protection system to be developed that would protect school bus passengers in most accident scenarios.

7. One of the primary causes 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.

8. The overall injury risk to occupants in motorcoach accidents involving rollover and ejection may be reduced significantly by retaining the occupant in the seating compartment throughout the collision.

9. New occupant crash protection systems for motorcoaches should be tested to uniform performance standards developed by the National Highway Traffic Safety Administration that are based upon actual crash testing of motorcoaches to ensure occupant safety.

10. Equipping motorcoach side windows with advanced glazing may decrease the number of ejections of unrestrained passengers during motorcoach accidents and decrease the risk of serious injuries to restrained passengers during motorcoach accidents.

11. Because the increased size of passenger windows in motorcoaches may affect roof strength, rollover strength standards must be developed to take into account the effect of typical window dimensions.

12. The U.S. Department of Transportation does not have standard definitions or classifications for the various bus types.

13. The Fatality Analysis Reporting System (FARS) is not a reliable source for identifying the number of fatal occupant ejections in motorcoaches.

14. The incorporation of bus identification into the vehicle identification number and the expansion of the use category will correct some of the inaccuracies in FARS data, but without standard definitions and accurate classification of buses within FARS, incomplete data and inaccuracies will still exist.

15. The Model Minimum Uniform Crash Criteria do not provide specific enough guidance to the States on bus body type coding.

16. School bus accident injury data are incomplete, and, therefore, injuries cannot be reliably estimated.

17. The use of on-board recorders may help reduce the accident rates of vehicle fleets.

18. On-board recorders are needed to provide quantitative data to evaluate the dynamics of bus crashes.

19. Establishing on-board recording standards for highway vehicles will provide a necessary foundation for the future use of on-board recorders.

Recommendations

To the U.S. Department of Transportation:

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. (H-99-43)

Once the standard definitions and classifications for each of the different bus 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. (H-99-44)

To the National Highway Traffic Safety Administration:

In 2 years, develop performance standards for school bus occupant protection systems that account for frontal impact collisions, side impact collisions, rear impact collisions, and rollovers. (H-99-45)

Once pertinent standards have been developed for school bus occupant protection systems, require newly manufactured school buses 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-99-46)

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-99-47)

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-99-48)

Expand your research on current advanced 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-99-49)

In 2 years, develop 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-99-50)

Once performance standards have been developed for motorcoach roof strength, require newly manufactured motorcoaches to meet those standards. (H-99-51)

Modify your methodology to collect accurate, timely, and sufficient data on passenger injuries resulting from school bus accidents so that thorough assessments can be made relating to school bus safety. (H-99-52)

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

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

To the National Association of Governors' Highway Safety Representatives:

In conjunction with the U.S. Department of Transportation, amend the Model Minimum Uniform Crash Criteria's bus configuration coding to comply with standard definitions and classifications of buses. (H-99-55)

To the bus manufacturers:

> Cooperate with the U.S. Department of Transportation in the development of standard definitions and classifications for each of the different bus body types. (H-99-56)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR.
Member

Adopted: September 21, 1999

Appendix A

Public Hearing Agenda

NATIONAL TRANSPORTATION SAFETY BOARD

PUBLIC HEARING AGENDA ON BUS CRASHWORTHINESS AND SURVIVABILITY:

INTERNATIONAL AND DOMESTIC PERSPECTIVES ON BUS OCCUPANT PROTECTION

PURPOSE

To explore what can be done to protect occupants in bus crashes, to include: bus standards and restraints used in other countries, types of possible restraints; and other types of injury-reducing mechanisms.

Any participant with special needs (as covered by the Americans with Disabilities Act) is asked to notify the hearing committee in advance of the program so necessary accommodations can be made.

OPENING STATEMENTS

10:00 a.m. - 10:30 a.m.

PANEL 1: INTERNATIONAL REGULATIONS

10:30 a.m. - 1:00 p.m.

WITNESSES

Robert Missen	European Union
Peter Makeham, FORS	Australia
Dan Davis, Transport Canada	Canada
Don Bischoff, NHTSA	United States

LUNCH

1:00 p.m. - 2:15 p.m.

PANEL 2: RESEARCH

2:15 p.m. - 4:45 p.m.

WITNESSES

Dr. Dusan Kecman, CIC	European Union
Peter Makeham, FORS	Australia
Bill Gardner, Transport Canada	Canada
Dr. Joseph Kanianthra, NHTSA	Other Restraint Alternatives
Dr. James McElhaney, Duke	Biomedical Engineer

BREAK

4:45 p.m. - 5:00 p.m.

PANEL 3: INDUSTRY PERSPECTIVES

5:00 p.m. - 10:15 p.m.

WITNESSES

Panel 3A: School Buses and Transit

Charlie Gauthier, NASDPTS	School Bus Transportation
Douglas Freeman, Blue Bird	U.S. School and Transit Bus Manufacturers

DINNER

(7:00 p.m. - 8:15 p.m.)

Panel 3B: Motor Coaches

Norm Littler, UMA	Motor Coach Operators
Paul Murphy, MCI	Motor Coach Manufacturers
Nicolas Strumane, Van Hool	European Bus Manufacturers
Dennis McConnell, McConnell Seats	Australian Seat Manufactuers

CLOSING STATEMENT

10:15 p.m. - 10:30 p.m.

Appendix B

Federal Motor Vehicle Safety Standards for Buses[1]

Federal Motor Vehicle Safety Standards Affecting Buses (Precrash)

Small Bus Only[a]	School Bus Only[b]	Number	Standard
		101	Control Location, Identification, and Illumination
		102	Transmission Shift Lever Sequence
		103	Windshield Defrosting and Defogging
		104	Windshield Wiping and Washing System
		105	Hydraulic Brake Systems
		106	Brake Hoses
		108	Lamps, Reflective Devices, and Equipment
		111	Rearview Mirrors
		113	Hood Latches
		116	Motor Vehicle Brake Fluids
		119	New Pneumatic Tires
		120	Tire Selection and Rims
		121	Air Brake Systems
		124	Accelerator Control Systems
	✓	131	School Bus Pedestrian Safety Devices

a. Includes small school buses (GVWR ≤ 10,000 pounds).
b. Includes both large and small school buses.

[1] All FMVSS are from 49 CFR Part 571.

Federal Motor Vehicle Safety Standards Affecting Buses (Crash and Postcrash)

Small Bus Only[a]	School Bus Only[b]	Number	Standard
✓		201	Occupant Protection in Interior Impact
✓		202	Head Restraints
✓		203	Impact Protection for the Driver
✓		204	Steering Control Rearward Displacement
		205	Glazing Materials
		207	Seating Systems (Driver)
		208	Occupant Crash Protection (Driver)
		209	Seat Belt Assemblies
		210	Seat Belt Assembly Anchorages
✓		212	Windshield Mounting
✓		214	Side Impact Protection
		217	Bus Emergency Exits and Window Retention and Release
✓		219	Windshield Zone Intrusion
	✓	220	School Bus Rollover Protection
	✓	221	School Bus Body Joint Strength
	✓	222	School Bus Passenger Seating and Crash Protection
✓		301	Fuel System Integrity
		302	Flammability of Interior Materials
✓		303	Fuel System Integrity of Compressed NG Vehicles
		304	Compressed Natural Gas Fuel Container Integrity

a. Includes small school buses (GVWR ≤ 10,000 pounds).
b. Includes large and small school buses.

Federal Motor Vehicle Safety Standards Applicable to School Buses[a]

	GVWR ≤ 10,000 lb.	GVWR > 10,000 lb.
Occupant Protection Standards	201, 202, 203, 204, 205, 207, 208, 209, 210, 212, 214, 217, 219, 220, 221, 222	205, 207, 208, 209, 210, 217, 220, 221, 222
Precrash Standards	101, 102, 103, 104, 105, 106, 108, 111, 113, 116, 119, 120, 121, 124, 131	101, 102, 103, 104, 105, 106, 108, 111, 113, 116, 119, 120, 121, 124, 131
Postcrash Standards	301, 302, 303, 304	301, 302, 303, 304

a. Standards 212, 214, 219, 301, and 303 are dynamically tested.

Occupant Protection Requirements for Buses

	Seating Position			Side Impact	Fuel System Integrity
	Driver	**Passenger**	**Dynamic**		
Bus ≤ 8,500 lb.	Lap/Shoulder Belt	Lap/Shoulder and Lap belt[a]	✓	✓	✓
Bus 8,500–10,000 lb.	Lap/Shoulder Belt	Lap/Shoulder and Lap Belt[b]		✓	✓
Bus > 10,000 lb.	Lap Belt				
School Bus ≤ 10,000 lb.	Lap/Shoulder Belt	FMVSS 222 Lap Belt		✓	✓
School Bus > 10,000 lb.	Lap Belt	FMVSS 222			✓

a. Lap/shoulder belts are located at outboard positions; lap belts only are located at the center positions.
b. Restraints the same as those under 8,500 lb.

Summaries of Crash and Postcrash Standards

FMVSS 201 Occupant Protection in Interior Impact—This standard specifies requirements to afford impact protection for occupants. It applies to passenger cars and to multipurpose vehicles, trucks, and buses with a GVWR of 4,536 kilograms or less, except that the requirements for upper interior components do not apply to buses with a GVWR of 3, 860 kilograms.

FMVSS 202 Head Restraints—This standard specifies requirements for head restraints to reduce the frequency and severity of neck injury in rear-end and other collisions. This standard applies to passenger cars, and to multipurpose passenger vehicles, trucks, and buses with a GVWR of 10,000 or less. For school buses, this standard only applies to the driver's seating position.

FMVSS 203 Impact Protection for the Driver—This standard specifies requirements for steering control systems that will minimize chest, neck, and facial injuries to the driver as a result of impact. This standard applies to passenger cars and to multipurpose passenger vehicles, trucks, and buses with a GVWR of 10,000 pounds or less. However, it does not apply to vehicle that conform to the frontal barrier crash requirements of FMVSS 208 by means of other than seat belt assemblies. It also does not apply to walk-in vans.

FMVSS 204 Steering Control Rearward Displacement—This standard specifies requirements limiting the rearward displacement of the steering control into the passenger compartment to reduce the likelihood of chest, neck, or head injury. This standard applies to passenger cars and to multipurpose passenger vehicles, trucks, and buses. However, it does not apply to walk-in vans.

FMVSS 205 Glazing Materials—The purpose of this standard is to reduce injuries resulting from impact to glazing surfaces, to ensure a necessary degree of transparency in motor vehicle windows for driver visibility, and to minimize the possibility of occupants being thrown through the vehicle windows in collisions. This standard applies to glazing materials for use in passenger cars, multipurpose vehicles, trucks, buses, motorcycles, slide-in campers, and pickup covers designed to carry persons while in motion.

FMVSS 207 Seating System—The purpose of this standard is to establish requirements for vehicle seats, and their attachment and installation in order to minimize injury to occupants during a crash. This standard applies to passenger cars, multi-purpose passenger vehicles, trucks, and buses. The applicability of this safety standard for buses applies only to the driver seat position.

The seat must be able to withstand a force 20 times the weight of the seat, applied both forward and rearward. Also, the seat must be able to withstand this force when the seat is adjusted to any position. If the seat has seat belt assemblies attached directly to the seat, the seat must be able to withstand the additional forces imposed by FMVSS 210 for seat belt anchorages simultaneous with the forces required for FMVSS 207. In addition, the seat must also be able to withstand a rotational moment of 3,300 inch-pounds with the seat in the rearmost travel position.

FMVSS 208 Occupant Crash Protection—The purpose of this standard is to reduce the number of vehicle occupant deaths and the severity of injuries by specifying vehicle crashworthiness requirements. These requirements limit the forces and accelerations measured on anthropomorphic dummies in crash tests. The standard also specifies equipment requirements for active (manual) and passive (automatic) restraint systems.

This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses. Buses with a 10,000 pound GVWR or less are required to have a lap and shoulder belt at the driver's position and all outboard seating positions and a lap belt at all inboard seating positions. School buses with a 10,000 pound GVWR or less must have a lap and shoulder belt at the driver's position and either a lap belt or a lap shoulder belt at all rear passenger positions. This standard does not provide protection for bus occupants in buses over 10,000 pounds GVWR.

For buses over 10,000 pounds GVWR the requirement of FMVSS 208 is met through the installation of an FMVSS 209-approved seat belt assembly (or other automatic crash protection device) for the driver seat position. The pelvic portion of such a belt assembly shall include either an emergency locking retractor or an automatic locking retractor.

FMVSS 209 Seat belt Assemblies—The purpose of this standard is to specify requirements for all seat belt assemblies in passenger cars, multipurpose passenger vehicles, trucks, and buses.

The initial requirement is that a designated seat belt assembly is to be designed for use by one, and only one, person at any one time. The seat belt shall provide pelvic and/or upper torso restraint. The hardware and webbing shall be free from burrs and sharp edges. The seat belt assembly buckles shall be readily accessible and easily released, while minimizing the possibility of inadvertent release. Each belt assembly shall be marked as to the manufacturing source and the date of manufacture. The belt assembly webbing shall a minimum of 1.8 inches width, and have a minimum breaking strength of 6,000 pounds for a lap belt only, 5,000 pounds for a lap belt used in conjunction with a shoulder belt, and 4,000 pounds for shoulder belt used in conjunction with a lap belt. The elongation shall not exceed 20 percent at a 2,500 pound force for a lap belt used singularly, or 30 percent at 2,500 pounds for a lap belt and 40 percent at 2,500 pounds for a shoulder belt used in conjunction. The belt webbing shall not significantly degrade due to exposure to sunlight, micro-organisms, or from abrasion. The belt hardware shall also be temperature and corrosion resistant.

FMVSS 210 Seat belt Assembly Anchorages—The purpose of this standard is to establish requirements for the seat belt assembly anchorages to ensure their proper location for effective occupant restraint and establishes minimum strength requirement to reduce the likelihood of their failure.

This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses. As the seat belt installation requirement for buses over 10,000 pounds GVWR applies only to the driver seat position this standard is not relevant to, or applicable for, passenger seat positions on buses.

The seat belt anchorage point, either to the seat frame or floor of the vehicle, has various dimensional requirements designed to provide suitable belt geometry to allow occupants to sustain crash forces properly distributed to the skeletal portion of the body. For a manual lap or lap and shoulder belt, these anchorage points must be able to withstand a pull of 5,000 pounds, applied between 5 and 15 degrees from the horizontal. The tensile load must be applied in a period less than 30 seconds and be able to maintain such a load for at least 10 seconds.

FMVSS 212 Windshield Mounting—This standard establishes windshield retention requirements for motor vehicles during crashes. The purpose of this standard is to reduce crash injuries and fatalities by providing for retention of the vehicle windshield during a crash, thereby utilizing fully the penetration-resistance and injury-avoidance properties of the windshield glazing material and preventing the ejection of the occupants form the vehicle. This standard applies to passenger cars and to multipurpose passenger vehicles, trucks, and buses having a GVWR of 4536 kilograms or less. However, it down not apply to forward control vehicles, walk-in van-type vehicles, or to open-body type vehicles with fold-down or removable windshields.

FMVSS 214 Side Impact Protection—This standard specifies performance requirements for protection of occupants in side impact crashes. The purpose of this standard is to reduce the risk of serious and fatal injury to occupants of passenger cars in side impact crashes by specifying vehicle crashworthiness requirements in terms of accelerations measured on anthropomorphic dummies in test crashes, by specifying strength requirements for side doors and by other means. This standard applies to passenger cars and multipurpose passenger vehicles, trucks, and buses with a GVWR of 10,000 pounds or less, except for walk-in vans.

FMVSS 216 Roof Crush Resistance—The purpose of this standard is to reduce injuries and deaths due to crushing of the roof into the passenger compartment in rollover accidents.

This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses with a GVWR of 6,000 pounds or less. This standard does not apply to convertible passenger cars, school buses, or buses with a GVWR of 6,000 pounds or more.

A rigid, unyielding block test device, with a contact surface measuring 2.5 feet by 6 feet, is pressed against the edge of the vehicle roof at a shallow angle. The block is loaded to provide a downward force of 1.5 times the unloaded weight of the vehicle. The crush of the roof shall not exceed 5 inches as measured by the contact surface of the test device.

FMVSS 217 Bus Emergency Exits and Window Retention and Release—The purpose of this standard is to minimize the likelihood of occupants being thrown from the bus and to provide a means of readily accessible emergency egress. This standard establishes requirements for the retention of windows other than windshields in buses and establishes operating forces, opening dimensions, and markings for bus emergency exits.

FMVSS 219 Windshield Zone Intrusion—This standard specifies limits for the displacement into the windshield area of motor vehicle components during a crash. The purpose of this standard is to reduce crash injuries and fatalities that result from occupants contacting vehicle components displaced near or through the windshield. This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses of 10,000 pounds or less GVWR. However, it does not apply to forward control vehicles, walk-in van-type vehicles or to open-body-type vehicles with fold-down or removable windshields.

FMVSS 220 School Bus Rollover Protection—The purpose of this standard is to reduce the number deaths and severity of injuries resulting from failure of the school bus body structure to withstand forces encountered in rollover crashes. This standard applies to school buses. This standard does not apply to other buses or to other vehicle categories.

A force is applied to the roof of the bus. The force is applied through a rigid, unyielding rectangular block test device called a force application plate. For buses with a GVWR of more than 10,000 pounds, the plate measures 36 inches wide and is 12 inches shorter than the vehicle roof. The plate is pressed against the roof of the bus with a force equal to 1.5 times the unloaded weight of the vehicle. With the force application plate vertical movement not exceeding 5.125 inches, the bus windows shall be operable per the process described in FMVSS 217.

FMVSS 221 School Bus Body Joint Strength—This standard establishes requirements for the strength of the body panel joints in school bus bodies. This standard originally applied to school buses with a GVWR exceeding 10,000 pounds. A recent final rule extends the requirement to all small school buses manufactured on or after May 5, 2000. Each body panel joint, where the various body panels are connected, must be able to withstand a load of at least 60 percent of the strength of the inherent body panel.

FMVSS 222 School Bus Passenger Seating and Crash Protection—This standard establishes occupant protection requirements for school bus passenger seating and restraining barriers. The purpose of this standard is to reduce the number of deaths and the severity of injuries that result from the impact of school bus occupants against structures within the vehicle during crashes and sudden driving maneuvers. This standard applies to school buses.

FMVSS 301 Fuel System Integrity—The purpose of this standard is to reduce deaths and injuries from fires that result from fuel spillage during and after motor vehicle crashes and from ingestion of fuels during siphoning.

This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses with a GVWR of 10,000 pounds or less and school buses with a GVWR greater than 10,000 pounds. The applicable fuel for these vehicles shall have a boiling point above 32 degrees F.

School buses with a GVWR of more than 10,000 pounds are tested by being struck by a moving barrier which approximates a 4,000-pound automobile. The bus test condition replicates a full load of fuel, operational fuel pump, and normal load condition of 120 pounds per occupant seat position. The moving barrier test device strikes the bus body at speeds up to and including 30 mph in a lateral and rear configuration per test procedure in FMVSS 208. The bus body is then rolled in quarter turn sequences. Fuel leakage must not exceed a rate of one ounce per minute.

FMVSS 302 Flammability of Interior Materials—This standard specifies burn resistance requirements for materials used in the occupant compartment of motor vehicles. The purpose of this standard is to reduce the deaths and injuries to motor vehicle occupants caused by vehicle fires, especially those originating in the interior of the vehicle from sources such as matches and cigarettes. This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses.

FMVSS 303 Fuel System Integrity of Compressed Natural Gas Vehicles—This standard specifies requirements for the integrity of motor vehicle fuel systems using compressed natural gas (CNG), including the CNG fuel systems of bi-fuel, dedicated, and dual fuel CNG vehicles. The purpose of this standard is to reduce deaths and injuries occurring from fires that result from fuel leakage during and after motor vehicle crashes. This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses that have a GVWR of 10,000 pounds or less and use CNG as fuel. This standard also applies to school buses regardless of weight that use CNG as motor fuel.

FMVSS 304 Compressed Natural Gas Fuel Container Integrity—This standard specifies requirements for the integrity of compressed natural gas (CNG) motor vehicle fuel containers. The purpose of this standard is to reduce deaths and injuries occurring from fires that result form fuel leakage during and after motor vehicle crashes. This standard applies to containers designed to store CNG as motor fuel on-board any vehicles.

Appendix C

Accident Simulation Assumptions and Limitations

Assumptions

- Simulated occupants represent the physical dimensions of the passengers in the actual accidents.
- The crash pulse developed is representative of actual crash dynamics.
- Critical injury values are accurate for children and young adults.
- Seat belts are well fitted and are in contact with the simulated occupant's body at the beginning of the accident.
- Simulated occupants are seated (except for the Holyoke accident) and forward facing unless indicated otherwise by passengers or witnesses.
- Default contact surface material definitions are representative of actual surfaces inside vehicle (such as seats, windows, windshields, walls, and doors).
- Seatbacks are not stiffened to reflect the additional load of a lap/shoulder belt.

Limitations

- Simulations cannot predict fatalities, only the probability of sustaining a head, neck, or chest injury.
- Simulations cannot provide an exact reconstruction of the actual accident, as they are limited by the inputs to the model. (However, simulations are representative of the accident.)
- Neck injuries are assessed only for flexion/extension injuries using Graphical Articulated Total Body (GATB). The MAthematical DYnamical MOdel (MADYMO) simulations only investigated neck injuries, using the National Highway Traffic Safety Administration's neck injury criteria, for the belted simulated occupants. Neck injuries for the unrestrained simulated occupants were not investigated because the simulated dummy that would predict neck injuries had not been developed when the simulations were conducted for this special investigation.
- Chest deflections are not measured with either MADYMO or the GATB, and thus may affect the accuracy of the chest acceleration values.
- Intrusion into the passenger compartment is not simulated with the Human Vehicle Environment (HVE) system, and consequently, it is not simulated with MADYMO.

- Accelerations are placed at the center of gravity of the vehicle, and, therefore, the higher accelerations at a point of intrusion or damage are not simulated for the occupant models.
- Head injury criteria is a measure of translational accelerations, not of angular accelerations.
- Active responses, such as whether a passenger was aware of the impending accident and braced, are unknown and therefore are not simulated.
- Finite element seat belts are not available with the GATB simulation in the HVE system. (They are available with the MADYMO simulation.)
- Elliptical contact surfaces to construct the seats are not available with the GATB simulation in the HVE system. (They are available with the MADYMO simulation.)

Appendix D

International Perspectives

The European Union

Initially, the organization of sovereign member states now known as the European Union (EU) was known as the European Economic Community, or the European Community. The Treaty of Rome established this organization, which now includes 15 member states,[1] in 1958 for the purpose of fostering free trade among its members. Initial legislation was aimed at facilitating the freer movement of goods and services within the EU. The EU has now expanded its activities to include creating uniform social and economic trade legislation.

The European Commission (Commission) is the administrative branch of the EU. The Commission's role is to ensure that existing legislation is applied correctly and to propose legislation. Since the EU has expanded its activities to include not only economic but also social legislation, the scope of the Commission's responsibilities has increased. The Commission now has considerable powers to propose legislation that addresses safety issues, particularly the issue of road safety.

The Commission itself is a nonelected body of 20 commissioners appointed by the member states for 5-year terms. Large countries (the United Kingdom, Germany, France, Italy, and Spain) have two commissioners each. Each other country has one commissioner. There are 24 directorates general within the Commission, each headed by one of the 20 commissioners (several of the commissioners oversee more than one directorate). A Director General who is the permanent administrative head of the Commission heads the European Commission.

The EU promulgates two types of legislation: regulations and directives. A directive is framework legislation; a regulation is rigid. For example, if a directive says that the maximum length of a motor vehicle in the EU is 12 meters (39.4 feet), each member state can interpret the rule as it wishes In this example, a member state can choose to have a maximum length of 11.5 meters (37.7 feet) with a positive tolerance of 0.5 meters (1.64 feet).

A regulation is rigid: its wording must be followed exactly. Member states cannot interpret or modify the requirement. The requirement that a tachograph be fitted on buses, motorcoaches, and trucks operated in the EU is an example of a regulation. The type of tachograph and its required functions are specifically detailed.

Generally, the Commission tends to propose directives because they give to the member states more flexibility to interpret their national laws. From a procedural point of

[1] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

view, both regulations and directives are enacted in the same manner. Once there is EU legislation on a subject, EU member states may not have additional national legislation that in any way contradicts or conflicts with the EU legislation, even if the national legislation predates the EU legislation.

When the legislation has been proposed, the onus is on any member state that has conflicting national legislation to lobby for adoption of its national law by the EU as a whole. The idea is that if it is sufficient in one state, it should apply equally in all others. If it is determined that a particular national requirement is not appropriate for the entire EU, a time-based derogation may be granted by the EU's Council of Ministers, allowing a member state to have different rules for a period of time.

Occupant Crash Protection on Buses

In 1990, the EU issued a directive requiring the installation of lap belts at all exposed seats[2] in motorcoaches first placed into service on and after July 1, 1992.

An EU representative reported to Safety Board staff that as a consequence of two catastrophic bus accidents in the United Kingdom, there was an outcry for the installation of seat belts on all seats on school transport vehicles, motorcoaches, and minibuses. Had there been no EU legislation requiring seat belts on motorcoaches, the United Kingdom could have required the fitting of seat belts at any or all passenger seats in motorcoaches. However, because 1990 EU legislation requiring lap belts only at exposed seats on motorcoaches already existed, the United Kingdom was prevented from passing legislation requiring seat belts at all passenger seats in all motorcoaches.

The United Kingdom requested that the already existing EU directive requiring lap belts only at exposed seats in motorcoaches be amended to require belts at all seats in new motorcoaches. The United Kingdom also enacted legislation requiring seat belts on buses and motorcoaches transporting children in the United Kingdom, particularly for school transport. By passing legislation based upon how a vehicle is used, the United Kingdom circumvented the Commission's seat belt directive on exposed seats. The United Kingdom legislation requires installation of belts on all new vehicles and the retrofitting of belts on all vehicles already in use that are used for transporting organized children's groups.

During the consideration of the United Kingdom's proposal that a directive be issued requiring seat belts on all passenger seats in motorcoaches, the Commission engaged the Cranfield Impact Centre in England to study the technical requirements for seat belts in motorcoaches. The study[3] concluded:

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[2] Directive 90/628/EC amending Directive 77/541/EEC. *Exposed* seats are those seats in coaches that do not have an energy-absorbing structure in front of them to protect a passenger who is thrown forward during a frontal impact or sudden stop. Such seats are typically located at the first passenger seat row, at the *courier,* or tour guide seat, in the entry/exit vestibule, at the center seat facing the aisle in the rearmost row, and at forward-facing seats immediately aft of a table or a door.

[3] Kecman, D., Ph.D., et. al., "Study of Technical Requirements for Fitment of Seat Belts in Buses and Coaches," Report to the European Commission, Cranfield Impact Centre, Ltd., Wharley End, Cranfield, Bedford MK43 OAL, England, February 1995.

> Lap and lap/shoulder belts can significantly reduce or prevent passenger ejection in all seating positions, particularly in rollovers, offset front, and major side impacts and also in exposed seating positions during front impacts. Ejection is a major cause of death and severe injury.

It took more than 2 years to get the necessary majority from the member states on the seat belt proposal. The seat belt legislation, Directive 96/36/EC, which was approved by the Council of Ministers in June 1996, requires:

> The fitting of lap/shoulder belts at all passenger seats on minibuses which have a gross laden weight[4] less than or equal to 3.5 metric tons (7,716 pounds). This requirement is applicable to all new vehicle designs[5] manufactured on and after October 1, 1999, and is applicable to all vehicles that are first placed into service on or after October 1, 2001.
>
> The fitting of lap/shoulder belts at all exposed seats, and the fitting of either lap/shoulder belts, or the fitting of lap belts aft of energy-absorbing seats, at all other passenger seats on M2[6] motorcoaches which have a gross laden weight greater than 3.5 metric tons (7,716 pounds). These requirements are applicable to all new vehicle designs manufactured on or after October 1, 1997, and are applicable to all vehicles that are first placed into service on or after October 1, 1999.
>
> The fitting of lap/shoulder belts at all exposed seats, and the fitting of either lap/shoulder belts, or the fitting of lap belts aft of energy-absorbing seats, at all other passenger seats on M3[7] motorcoaches. These requirements are applicable to all new vehicle designs manufactured on or after October 1, 1997, and are applicable to all vehicles that begin service on or after October 1, 1999.

The June 1996 seat belt directive permits an EU member state to require a motorcoach to comply with national legislation on seat belts. Yet, a vehicle does not have to meet the EU legislation's requirements unless the vehicle is a "new design" after October 1, 1999. This lead time allows member states to set higher, possibly more expansive, standards for already-existing motorcoach designs until that date. A member state, for example, could insist on lap/shoulder belts at all seats in its own motorcoaches now, but it can not refuse to permit the import of motorcoaches built to EU-approved standards that differ from the state's own national legislation. After October 1, 1999, an EU member state cannot refuse admission into its country for sale or use any motorcoach

[4] In determining the gross laden weight, a weight of 71 kilograms (156.5 pounds) is used for the weight of each person/seat provided on the coach or minibus subject to the seat belt legislation.

[5] A vehicle is a *new design* if it differs from already-approved types in any one or more of the following: body work manufacturer, chassis manufacturer, vehicle class (I, II, III, A, and B), body work concept (single/double deck, articulated, low floor), passenger capacity limit category, or a gross laden weight differing by more than 10 percent from any already approved types.

[6] M2 vehicles have more than 8 seats in addition to the driver's seat and a maximum weight of not more than 5 metric tons (11,023 pounds).

[7] M3 vehicles have more than 8 seats in addition to the driver's seat and a maximum weight of more than 5 metric tons (11,023 pounds).

that meets the seat belt directive coming into effect on that date. A similar situation exists for minibuses, with the cut-off date for minibuses being October 1, 2001.

Although an EU member state cannot require higher seat belt standards on motorcoaches first placed into service after October 1, 1999, the state can enact national legislation limiting how motorcoaches with lap belts at nonexposed seats are used. For example, for some time motorcoaches in Germany have been allowed to operate at 100 km/h (62 mph) only if the exposed seats have occupant restraints. If such seats do not have occupant restraints, German law limits the motorcoach's maximum operating speed to 80 km/h (50 mph). At this time, nothing precludes this type of legislation in the EU member states since the legislation does not conflict with existing EU legislation and will not conflict with the new seat belt directive when the directive becomes effective.

According to the Director General's office, none of the countries within the EU have vehicles dedicated to pupil transportation. There are no yellow school buses. The majority of students travel to and from school either on municipal scheduled buses or municipal buses that are chartered for school transportation. Motorcoach buses are also chartered for school transportation and are usually the oldest buses in the fleet. A small number of private schools provide transportation in minibus vehicles.

According to the EU representative, the United Kingdom requires that vehicles that are used primarily for the transportation of children have seat belts and that the belts be worn. The question of who is responsible and liable for making the children wear the belts has not been decided.

EU Studies of Bus Accidents

In 1985, the EU commissioned the Motor Industry Research Association to investigate motorcoach bus safety. The report[8] concluded that:

> Although the casualty rate per passenger kilometer for motorcoach travelers is low in relation to other forms of transport, when collisions do occur, large numbers of people can be injured.… The ejection of passengers which increase the chances of injury substantially would probably be best prevented by the use of lap belts by passengers….
>
> The protection of passengers in frontal impacts depends mainly on attenuating the contact between the passenger and the seat that he is facing. Either the use of a seat belt or controlled collapse of the seat can achieve this. A legislative requirement should be established to improve seat crashworthiness that enables both options to be available to the manufacturer.

A representative of the Commission advised the Safety Board that the EU promulgated the directive requiring lap/shoulder belts on smaller vehicles on the grounds that small vehicles perform like cars in crashes and, therefore, should meet analogous

[8] The Motor Industry Research Association, Watling Street, Warwickshire CV10 0TU, England, "EEC Coach Safety Investigation," Report No. K454293, Investigation into Ways of Improving Coach Safety, October 17, 1985.

requirements. The EU determined that most injuries and fatalities associated with the smaller buses happened while the passengers were either boarding or alighting. On larger vehicles, the evidence showed that approximately half the deaths and serious injuries were caused by passengers being ejected during rollovers rather than being hurt during frontal impacts. Therefore, the EU's primary concern about accidents involving the larger vehicles is to keep the passengers in place, not to protect them against impact injury.

The representative from the Cranfield Impact Centre stated in an interview that the Centre's research strongly supported the view that occupant protection is not just seat belts but a total system including the belts, the seats, and the anchorages. He said that putting seat belts on an improper seat can be disastrous and that restraint combinations have been seen that performed worse with seat belts, especially lap belts, than without.

He also said that some car manufacturers who construct minibuses derived from van designs objected to the seat belt legislation. The manufacturers anticipated problems adapting their existing M2 minibus designs with gross laden weights of 3.5 metric tons (7,716 pounds) or less to accommodate lap/shoulder belts. For this reason, the legislation mandating lap/shoulder belts for these smaller vehicles will become effective 2 years after the legislation for the larger vehicles does.

EU Legislation for Seat and Seat Anchorage's Strength

Directives specifying requirements for the strength of passenger seats, seat anchorages, and seat belt anchorages were amended to accommodate the installation of seat belts on all motorcoach passenger seats. This legislation did not require that motorcoaches placed into service before October 1997 be retrofitted with seat belts.

The EU seat belt-anchorage directive specifies that the required strength of the seat belt anchorages depends on the mass (gross weight) of the vehicle in which the anchorage is installed. For seat belt-anchorage systems attached to the seats: M2 vehicles are required to have seat anchorages capable of sustaining a quasi-static load equal to approximately half the load required for anchorages on an M1 vehicle, and M3 vehicles are required to have anchorages capable of sustaining a quasi-static load equal to approximately one-third the load required for an M1 vehicle anchorage system. In lieu of a quasi-static test, a sled test can be performed to test the seat anchorage system on M3 vehicles. For the sled test, two 50th-percentile male dummies are placed in the seat and restrained. The maximum sled deceleration must be at least 8 g, and the velocity change, Delta V, must be at least 18.6 mph.

The EU also requires that seats be energy absorbing to protect the unbelted occupant from behind.

EU Legislation Mandating Seat Belt Use and Retrofit

Two issues that were deliberately not addressed in the EU seat belt legislation relate to retrofitting and the mandatory use of seat belts. The Transport Directorate did not want to require retrofitting because existing vehicles may not be designed for seat belts. In addition, retrofitting could be dangerous if the seats are not energy-absorbent and/or the belt and seat anchorages can not withstand crash loading.

Furthermore, testing retrofitted seat belts is difficult. Without a test procedure, it is not possible to verify whether belts actually perform their necessary function in a crash. Motorcoach operators can retrofit if they wish, since the EU legislation is silent on this issue; and some motorcoach designs now in use may accommodate retrofitting.

The Commission said that the EU would probably not consider legislation on the mandatory use of seat belts on motorcoaches for some considerable time. This is because the vast majority of the European motorcoach fleet is not equipped with seat belts at all seats. Approximately 35 percent[9] of motorcoaches operated in 1997 in the EU member states have lap belts at the exposed seats. The implementation date for installing seat belts for present M3 and M2 motorcoach designs with a gross laden weight greater than 3.5 metric tons (7,716 pounds) was October 1999. Consequently, given that the average life of a motorcoach is 15 years, it will probably be 2005 or 2006, before even half of the fleet is fitted with seat belts.

Another issue that has to be addressed before the Commission will consider legislation mandating seat belt use is determining the liability for compliance. A Commission representative advised the Safety Board that the pragmatic approach would be to equip vehicles with seat belts and give every occupant the choice of wearing a seat belt or not. Ideally, motorcoach seats would be designed in such a way that if one passenger is wearing a seat belt and the passenger behind him is not, the belted passenger will not be injured by the forward movement of the unbelted passenger during a collision. The seat will absorb the energy of the unbelted occupant, causing minimal injuries to the unbelted passenger.

Bus Rollover

The EU has proposed legislation on the rollover strength of buses and motorcoaches. The Commission’s Regulation 66 was the basis for the legislation. The Commission believed that a directive specifying rollover strength in the bus construction standards is essential for ensuring the effectiveness of the seat belt legislation. The Commission believed that mandating seat belts without a rollover strength requirement increases the risks to passengers if the roof crushes downward and decreases the available space. This would occur only during 180-degree or greater rollovers. Ejections, which cause half the fatalities and injuries, can occur when the motorcoach simply rolls onto its side. At present, only the United Kingdom and Spain require compliance with the Commission’s rollover strength requirements.

The proposed EU standard includes the requirement that any bus or motorcoach pass a tilt test. The standard requires that a single-deck vehicle be able tilt up to 35 degrees without rolling over. The ability to pass the tilt test has been a requirement in the United

[9] Estimated using an average coach life of 15 years with an average of 7 percent of the coach fleet being replaced each year. Since the legislation was passed 5 years ago in 1992, 5 X 7= 35 percent.

Kingdom for a number of years. Compliance with the tilt test indicates that the vehicle is less likely to roll over during violent avoidance maneuvers.

Australian Bus Safety Issues

Australia has two categories of buses: urban buses, which are for both seated and standing passengers, and motorcoaches, which are predominately for seated passengers. Australia does not have school buses similar to those in the United States, which have to meet higher standards. Australia has standards[10] similar to those of the United States for braking, lighting, and fuel tank integrity. In addition, Australian buses have speed limiters and are required to meet a bus rollover standard.[11] The standards for occupant protection differ according to the category of bus.

Occupant Restraints

In motorcoach buses, the Australian standard[12] requires lap/shoulder belts at all seating positions. As with the EU requirement, the minimum seat anchorage system strength for a seat with a unitized seat belt system can be established using a sled test. For the test, two 50th-percentile male dummies are placed in the seat and restrained. The sled deceleration for the test must be at least 20 g (approximately twice the EU requirement) and the velocity change, Delta V, must be at least 30 mph. Regulators who designed the standard wanted to protect restrained occupants from the unrestrained occupants seated behind them. Therefore, when conducting a sled test, unbelted dummies are placed in the seat behind the seat with the belted dummies if that seat exists in the actual coach. The injury criteria for the unbelted occupant are not measured. (The EU sled test does not require the unbelted dummies in the rear seat.) Australia does not require that the seat be energy absorbing to protect the unbelted passenger from behind. The standard also requires that six of the seats have upper tethers to use in conjunction with the child restraints.

In Australia, traveling by motorcoach is 20 times safer than traveling by private car,[13] yet the new standards were the outcome of two serious motorcoach accidents in the late 1980s. In the first accident, a motorcoach and tractor-semitrailer collided head on; 20 people were killed, and 15 were injured. Three months later on the same highway, two motorcoaches collided head on, and 35 people were killed and 39 injured. Analysis[14] of both accidents found that several of the seat structures and mountings in all the motorcoaches involved failed and caused many of the injuries. In response to these seat system failures, regulations began to be developed for new seat systems based upon the European standards. When it was found that the Stratos Seat Company had developed a seat that tested well when subjected to a crash pulse deceleration approximately twice the European requirement, that

[10] The standards are called Australian Design Rules and are the performance and design requirements for motor vehicles.

[11] Australian Design Rule Number 59.

[12] Australian Design Rule Number 68.

[13] "Bus Crashes and Occupant Protection, A Brief Summary and Analysis of Crashes Involving Long Distance Coaches, Australia 1988 to 1994," K.B. Smith, Federal Office of Road Safety, July, 1998.

[14] "Cost Benefit Analysis of Retrofitting Occupant Protection Measures to Existing Buses," K.B. Smith, November 21, 1994.

incorporated lap/shoulder belts, that could withstand an impact from behind of unbelted occupants (not an EU requirement), and that could be installed in motorcoaches at an affordable price, the standard was revised to incorporate those conditions.

These regulations went into effect for all motorcoaches manufactured since 1994; and, currently, most motorcoaches have the new seat-restraint systems. Also, the government developed a code for the retrofit of existing motorcoaches using the 10-g seats and lap belts. This is not a mandatory requirement but a voluntary code.

A motorcoach with the new seat system has had an accident. Fully occupied, it struck a culvert at highway speeds. Two passengers were fatally injured; neither had been restrained. One had been walking down the aisle; and the other, the reserve driver, had been in the sleeper cab, which was at in the back of the bus. More studies are being done to determine the performance of the new occupant restraint system.

In Australia, if a restraint is provided, it must be used, and its use is enforced by the state police. According to studies,[15] approximately 95 to 98 percent of front-seat passengers and 80 to 85 percent of rear-seat passengers use the restraints. In buses, the driver is not responsible if an occupant does not use an available restraint. The driver is responsible only for providing information about the laws to the passengers. In the case of a motorcoach, a passenger who does not wear a seat belt can be fined $200 to $300, and the driver gets demerit points on his license. There are no controls in place to ensure that school-age children utilizing the bus for pupil transportation wear restraints.

Rollover Standards

All buses in Australia are required to meet a bus rollover standard,[16] which is based on the United Nations Economic Commission for Europe (UNECE)[17] Regulation 66. The standard requires that the bus be able to maintain an internal space within specified dimensions after it is tipped onto its side. The results of crash testing motorcoaches were used in developing the standard and in validating computer simulations. The validation made it possible to rely more on computer simulations than on actual crashes.

Australia has had crashes in which rollovers and partial ejections have caused injuries that were not life threatening but were extremely debilitating. Preventing occupant ejection has been a priority.

[15] *Development of an Australian Design Rule for Seat Belts in Heavy Omnibuses,* Alan Gascoyne, Keith Seyer, Federal Office of Road Safety, Australia, 1994.

[16] Australian Design Rule Number 59.

[17] The UNECE is a subgroup of the United Nations. It was started at the end of World War II to promote trade in Europe by harmonizing the requirements of various countries. Membership is voluntary, and member states do not have to comply with UNECE legislation.

Appendix E

History of Restraint Recommendations to the FHWA and to NHTSA

Recommendation	Action	Response
Safety Recommendation H-68-18 asked the FHWA to expedite the proceeding initiated under Part II of the Interstate Commerce Act, Docket Ex Parte No. MC-69, May 27, 1966: to inquire into the operations of motor carriers of passengers in order to determine whether it is necessary or desirable to adopt regulations and establish standards which would require carriers to install, provide, and maintain seat belts for the use of passengers and drivers.	Closed—Superseded by H-73-42 between December 12 and 16, 1985. (For more information, see response to H-70-4.)	In its January 17, 1969, letter, the FHWA indicated that initial action on the docket Ex Parte No. MC-69, initiated in May 1966, was delayed pending the transfer to DOT on April 1, 1967, of responsibility for the FMVSS. The FHWA stated that it does not support the Safety Board's position that belts should be required for bus occupants but does intend to require installation and use of lap belts for drivers of buses in interstate commerce. In its August 23, 1974, letter, the FHWA indicated that tests conducted by BMCS show that seat belts are used by only a small percentage of occupants. This low usage rate, combined with the small number of bus fatalities subject to BMCS jurisdiction and the estimated number of injuries that might be prevented by belt usage, indicates negative cost/benefits. In its May 2, 1979, letter, the FHWA stated that the bus passenger feasibility study indicates that lap belts for all seats on both old and new intercity buses would be feasible if used 100 percent of the time.
Safety Recommendation H-70-4 asked the FHWA to take additional steps to make available to bus passengers convenient restraints to prevent ejection in a crash or rollover, such as are available to motorists and airline passengers, so that passengers will not be denied the opportunity to employ them.	Closed—Superseded by H-73-42 between December 12 and 15, 1985. (*Note:* From 1968 through 1973, the Safety Board issued several safety recommendations calling for studies or rules regarding the availability of seat belts on buses. As a housekeeping measure, the Board closed three of the four remaining recommendations on the issue: H-68-18, H-70-4, and H-73-7.)	In its April 7, 1970, letter, the FHWA advised the Safety Board of an ongoing study and proposed rulemaking on driver seat belt requirements. The FHWA also said that it decided not to require passenger belts because of retrofit problems. In its August 8, 1974, letter, the FHWA indicated that tests conducted by the BMCS show seat belt usage by only a small percentage of occupants. This low usage rate, combined with the small number of bus fatalities subject to BMCS jurisdiction (31 in 1972) and the estimated number of injuries that might be prevented by belt usage, indicates negative cost/benefits. In its May 2, 1979, letter, the FHWA stated that the bus passenger seat belt feasibility study indicates that lap belts for all seats on both old and new intercity buses would be feasible if used 100 percent of the time.

Recommendation	Action	Response
Safety Recommendation H-71-10 asked the FHWA to expand its rulemaking concerning section 393.33 (seat belts) of the FMCSR in 49 CFR 393 to require in all buses, the installation of occupant restraints, active or passive, that conform to the FMVSS 209 and that will retain the passengers, as well as the driver, in their seats during collision and rollover.	Closed—Unacceptable Action on October 29, 1975.	In its August 23, 1974, letter, the FHWA stated: The BMCS has replied to this recommendation on numerous occasions. Tests conducted by BMCS show seat belt usage by only a small percentage of occupants. This usage fact and the small number of bus fatalities subject to BMCS jurisdiction (31 in 1972) and the calculation of the number of injuries that might be mitigated by belt usage, indicate negative cost/benefits. In many buses, belt installation would be impracticable because they were not designed for belt use and could not withstand the floor loadings.
Safety Recommendation H-71-11 asked NHTSA, in the development of its rulemaking related to Docket 2-11, Bus Seats, to include the requirement for the installation of seat belt assemblies, as well as seat belt anchorages, for intercity buses.	Closed—Acceptable Action on January 1, 1980.	In its April 6, 1971, letter, NHTSA indicated that it is developing an NPRM on bus passenger seating and crash protection. This NPRM would require substantial upgrading in bus seating over current design and is being approached from a seating system standpoint to include a combination of the following: effective energy-absorbing material on all rigid seat surfaces, higher seat backs, strengthening of seat structures and anchorages. In addition, safety belts are being considered. The seating system described will provide a reasonable level of passive restraint protection in most crash configurations.
Safety Recommendation H-71-34 asked the FHWA to expand its rulemaking concerning section 393.95 (seat belts) of the FMCSR in to require in all interstate buses the installation of occupant restraints, active or passive, that conform to the FMVSS 209.	Closed—Unacceptable Action on October 29, 1975.	In its June 6, 1971, letter, the FHWA, in response to Safety Recommendations H-71-34 through -36, restated its position that lap belts used in connection with currently installed bus seat configurations would act as a fulcrum and cause the upper torso of the body to target the head into the adjacent structures in ways that would increase the risk of injury. The FHWA does not recommend seat belts or “fasten seat belt” signs. In its June 14, 1971, letter, NHTSA stated: There is little evidence to support the conclusion that the use of lap belts would have significantly reduced the injuries of the contained passengers. The problem of crash protection for bus occupants is presently being approached from the seating system standpoint (combination of effective energy-absorbing material on all rigid surfaces, higher seat backs, and strengthening of seat surfaces and anchorages).

Recommendation	Action	Response
Safety Recommendation H-71-35 asked the National Highway Safety Bureau (now NHTSA) in the development of its rulemaking related to Docket 2-11, Bus Seats, to include the requirement for the installation of seat belt assemblies, as well as seat belt anchorages, for interstate buses.	Closed—Unacceptable Action on October 29, 1975.	See response to **Safety Recommendation H-71-34**.
Safety Recommendation H-71-87 asked the FHWA to take positive steps to make available to bus passengers convenient restraints to prevent ejection in a crash or rollover. (This recommendation, with similar intent but varying language, had been made by the Safety Board in four previous reports on interstate bus crashes.)	Closed—Unacceptable Action on March 29, 1975.	In its December 22, 1971, letter, the FHWA reiterated its position that the solution to the occupant-protection problem will be a passive restraint approach, designed to minimize passenger ejection and to mitigate injury caused by contact with interior surfaces. The FHWA further stated that containment can be effectively assured by requirements governing seat configuration and the mounting and latching of windows.
Safety Recommendation H-73-1 asked the FHWA and NHTSA to institute appropriate rulemaking action to require that all newly constructed interstate-type buses be equipped with approved occupant restraints, active or passive, for all seating positions in such buses.	Closed—Acceptable Action on January 1, 1980.	In its March 21, 1973, letter, NHTSA stated: With regard to the recommendation to provide seat belts for all passengers on intercity buses, you may be interested in the recent Notice of Proposed Rulemaking, *Bus Passenger Seating and Crash Protection,* printed in the *Federal Register*, Volume 38, No. 35, on February 22, 1973. The National Highway Traffic Safety Administration in this proposal would require bus passenger seats which are stronger and safer and which afford greater protection to bus passengers. In addition, an alternative restraint system employing seat belts equipped with a warning system has been included in these proposed requirements. The standard as proposed would apply to buses of all types manufactured after September 1, 1974. In its August 23, 1974, letter, the FHWA indicated that this recommendation had previously been acted on by NHTSA and, therefore, required no further action by the BMCS. The BMCS further stated that the responses to the NPRM had been analyzed, and a revised NPRM, 49 CFR 571, Docket 73-3, Notice 2, was being issued with a proposed effective date of January 1, 1976.

Recommendation	Action	Response
Safety Recommendation H-73-7 asked NHTSA and the BMCS to take immediate action toward requiring the availability of seat restraints for passengers of buses in interstate commerce, with first attention given to restraints in newly manufactured buses.	Closed—Superseded on December 12, 1985.	In its April 23, 1973, memorandum, the FHWA stated: The Bureau has responded to Recommendation H-73-7, pertaining to occupant restraints, on numerous occasions, including the Safety Board's recent report on the Marshfield, Missouri, accident (Report No. NTSB-HAR-73-1). No additional data have become available to suggest a revision of our views on this matter. In its May 10, 1973, letter, NHTSA indicated that based on the Safety Board's recommendations and other available accident data and test data, it had issued a Notice of Proposed Rulemaking on Bus Passenger Seating and Crash Protection on February 15, 1973, noting that: This proposed rulemaking allows two options for occupant restraint. The first option offers passive restraint protection by means of very strong, well padded, high-backed seats which compartmentalize the passenger compartment for good passenger containment during most crashes. The second option offers active restraint protection, which includes padded high seat backs, lap belts, and warning system to assure a high degree of belt usage. NHTSA feels that allowing two approximately equivalent approaches to the passenger protection problem will minimize the cost burden by permitting bus operators to choose the system that best fits their particular operation.
Safety Recommendation H-73-18 asked NHTSA to require that seats on intercity buses be upgraded to provide a defined level of protection for passengers who do not use installed restraints and also to require the seat strength and seat belt performance standards called for in the proposed rulemaking.	Closed—Unacceptable Action on August 13, 1997.	NHTSA, in its August 13, 1974, letter, stated that it had determined that seating requirements cannot be justified based on cost/benefit studies and injury statistics indicating that seating improvements on intercity buses would not reduce injuries substantially.

Recommendation	Action	Response
Safety Recommendation H-73-42 asked the BMCS to take positive steps to make available to bus passengers convenient restraints to prevent ejection in a crash or rollover. (This recommendation, with similar intent but varying language, had been made by the Safety Board in seven previous reports on interstate bus crashes.)	Closed—Reconsidered on June 29, 1988.	In its February 11, 1974, memorandum, the FHWA, in response to Safety Recommendation H-73-42, stated: Both the Bureau of Motor Carrier Safety and the National Highway Traffic Safety Administration have faced the problem of occupant ejections in accidents. The combination of double-latched windows (BMCS Docket No. MC-21 and NHTSA Motor Vehicle Safety Standard No. 217, effective July 1 and September 1, 1973, respectively) and improved seating and crash protection in new buses (NHTSA Docket 73-3) approach the problem in a way we expect, in the long run, to be more effective, less costly and more easily accepted by the public. In its April 22, 1988, letter, the FHWA stated: In response to this recommendation, the FHWA initiated research which was conducted by the Indiana University. A copy of the research report, *Analysis for Need for Passenger Safety Belt Requirements in Intercity Buses*, was transmitted by our September 13, 1985, letter. The researchers concluded that none of the seat belt options studied had a favorable benefit/cost ratio at the anticipated voluntary passenger use rates. Based on this research, it was recommended that no requirements for passenger safety belts in intercity buses be issued. In its June 29, 1988, response to the FHWA's April 22, 1988 letter (see above), the Safety Board replied: The Safety Board's most recent major accident experience with passenger restraints in intercity buses is based on our investigation of the North Bergen, New Jersey; Brinkley, Arkansas; and Carney's Point, New Jersey bus accidents. During these investigations, it was observed: (1) Generally, the installation and use of lap belts would not have lessened the injury outcome for passengers who sustained minor to moderate injuries. (2) The injury outcome of the remaining passengers who sustained serious to fatal injuries in these accidents was less predictable. Normally, lap belts would not have lessened the injury severity for the serious to fatally injured passengers who were seated in areas which were intruded during impact. (3) However, in the North Bergen accident, the installation and use of lap belts might have reduced the injury severity of two passengers who were ejected out of non-intruded-upon areas into the rearward moving front structure of the bus. Based on these findings, it seems appropriate to classify Safety Recommendation H-73-42 as "Closed—Reconsidered." However, it should be noted that these observations were made in accidents involving primarily front/rear collisions and not in accidents involving bus rollovers. The Safety Board will continue to monitor intercity bus accidents to test these observations.

Appendix F

Summaries of Selected[1] Motorcoach[2] Accidents Investigated by the Safety Board From 1968 Through 1997

CASE 1

Date and Time	March 7, 1968, 3:47 p.m.
Date Report Adopted	December 18, 1968
Accident No.	NTSB/SS-H-3
Location	Near Baker, California
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	19 Fatal, 12 Nonfatal
Type of Crash	Head-On Collision With Automobile and Subsequent Overturn

A 1966 MCI Challenger Model MC-5A motorcoach on a regularly scheduled run was traveling in the eastbound median lane of Interstate Highway 15 when it collided nearly head on with an automobile being driven westbound in the same lane by an intoxicated driver. The force of the collision drove the automobile about 45 feet east of the point of impact, killing the automobile driver instantly and ejecting his body from the automobile.

After impact, the motorcoach swerved left into the median and overturned onto its right side. The motorcoach had four windows on each side; the windows were hinged at the top, latched at the bottom, and designed as emergency exits. During the collision and subsequent overturn, the motorcoach was twisted, causing some of the side windows to spring open. Portions of passengers' bodies, such as legs, arms, and hands, were ejected and protruded through the windows; and as the overturned motorcoach came to rest, at least three passengers were pinned under it.

Fire, fed by leaking power steering fluid and diesel fuel from the breached fuel tank, spread immediately throughout the motorcoach. The driver and 6 of the 14 passengers seated in the first four rows escaped through the windshield. Five passengers seated in the last three rows at the left rear of the motorcoach smashed the rear window and escaped through it.

[1] Forty crashes in which one or more passengers who sustained fatal injuries either were found inside the vehicle or were ejected, and one crash in which passengers survived but lost limbs because they were partially or completely ejected.

[2] Accidents 13, 20, 33, and 35 are not motorcoach fatalities and are not included in motorcoach data in the report.

The 19 passengers who did not escape died in the fire. A pathologist who partially examined 12 of the dead passengers reported that, although he observed fractured extremities, he observed no injuries which, of themselves, would have been fatal.

As a result of its investigation of this crash, the Safety Board recommended that the Federal Highway Administration (FHWA):

> H-68-18
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> Expedite the proceeding initiated under Part II of the Interstate Commerce Act, docket Ex Parte No. MC-69, dated May 27, 1966, to inquire into the operations of motor car5riers of passengers in order to determine whether it is necessary or desirable to adopt regulations and establish standards which would require carriers to install, provide, and maintain seat belts for the use of passengers and drivers.
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> The Safety Board said:
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> The experience in this case indicates definitely that restraint of drivers and occupants in their seats during rollover conditions is necessary to reduce initial injury, disorientation, and thus ensure more likelihood of timely postcrash escape from the vehicle. The FHWA Administrator in reaching his decision concerning a requirement that seat belts be available in buses should seriously consider this report and the Safety Board's conclusion. The Safety Board urges that a decision be made on this important matter, which has been under consideration for more than 22 months at the time this accident occurred, and more than 30 months prior to the date of this report.
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> The Safety Board also recommended that the FHWA:
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> H-68-25
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> As soon as possible, change the basis of its regulatory requirements intended to ensure escape from buses so that they are based upon tests of performance of occupants in escaping from buses standing or lying in all basic attitudes. In the development of test criteria, it is suggested that consideration be given to test procedures presently employed by the Federal Aviation Administration for the regulation of the adequacy of escape techniques and systems. Further, consideration should be given to adopting for buses, the airline practice of placing emergency escape instructions at each passenger location. It is further recommended that necessary regulations be expedited to ensure that no new types of buses go into service which have not been tested to ensure that all occupants can escape rapidly when the bus is in any of its basic attitudes after a crash. This Recommendation refers to Docket 2-10 of the National Highway Safety Bureau[3] as well as the Motor Carrier Safety Regulations.

[3] At the time this recommendation was issued, the National Highway Safety Bureau, predecessor of NHTSA, was part of the FHWA.

CASE 2

Date and Time	December 26, 1968, 2:40 a.m.
Date Report Adopted	January 23, 1970
Accident No.	NTSB/SS-H-5
Location	Near Beaver Falls, Pennsylvania
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	3 Fatal, 36 Nonfatal
Type of Crash	Run Off Road and Overturn

A chartered 1968 Challenger Model MC5A motorcoach traveling eastbound on Interstate Highway I-80 South traveled straight ahead as it entered a left curve and ran off the roadway to the right. The driver made a hard left turn, and the motorcoach yawed to the left and re-entered the roadway. After a hard right turn, the motorcoach again ran off the roadway to the right. Another hard left turn made as the driver again attempted to return to the roadway caused the motorcoach to vault and roll over onto its roof. After rolling over, the inverted motorcoach rotated 180 degrees and slid east down about 12 feet into a drainage gully, coming to rest facing west. Its roof and left side were lying on the bottom of the gully.

Thirteen passengers and the driver were hospitalized with moderate to severe injuries. Another 23 passengers were treated for minor injuries and released. One passenger, who had been seated in the right third-row window seat, was crushed between a seatback and a collapsed roof support. Another passenger, who had been seated in a window seat in the left ninth row, was partially ejected through the adjacent window and was pinned in the collapsed window frame as the motorcoach came to rest on its roof. Both victims died immediately.

A third passenger, who had been seated in the window seat immediately behind the driver, sustained injuries that caused death about an hour after the crash. She was ejected from her seat forward and to the right into the entrance stairwell.

The Safety Board concluded that occupant restraints would have reduced the number of injuries the surviving passengers sustained and possibly would have reduced the severity of the injuries sustained by the woman who died after the accident. The Board was uncertain whether restraints would have prevented the other two fatalities, because both fatalities resulted from structural damage.

As a result of its investigation of this crash, the Safety Board recommended that the FHWA:

<u>H-70-4</u>

Take additional steps toward making available to the bus-traveling public convenient restraints against being ejected from their seats in a crash, such as are available to motorists and airline passengers, so that passengers will not be denied the opportunity to employ them if they so desire.

The Board said that in its view:

A decision to make available suitable restraints which would reduce injuries is not dependent upon a showing that all passengers would use them, nor should it be limited by the fact that past bus passenger seat designs do not accommodate the lap belt type restraint. The retention of passengers in their seats during the crash phase is clearly desirable, as indicated by this case and others, and making restraints available is a first step in obtaining their use.

The Safety Board also recommended that the FHWA:

H-70-9

Review our recommendation in the report of the Interstate bus-auto collision near Baker, California, to change the basis of regulatory requirements intended to ensure escape from buses so that they are based upon tests of performance of occupants in escaping from buses standing or lying in all basic attitudes. In the development of test criteria, it is suggested that consideration be given to test procedures presently employed by the Federal Aviation Administration for the regulation of the adequacy of escape techniques and systems. Further, consideration should be given to adopting for buses, the airline practice of placing emergency escape instructions at each passenger location. It is further recommended that necessary regulations be expedited to ensure that no new types of buses go into service which have not been tested to ensure that all occupants can escape rapidly when the bus is in any of its basic attitudes after a crash. This recommendation refers to Docket 2-10 of the National Highway Safety Bureau, as well as the Motor Carrier Safety Regulations.

CASE 3

Date and Time	November 24, 1969, 5:15 a.m.
Date Report Adopted	February 10, 1971
Accident No.	NTSB/HAR-71-4
Location	Near Petersburg, Indiana
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	1 Fatal, 25 Nonfatal
Type of Crash	Collision With Automobile Followed by Motorcoach Overturn

A 1966 GMC Model PD4107 motorcoach on a regularly scheduled run was traveling southbound on Indiana Route 57 in heavy fog and darkness when the driver, believing headlights ahead indicated an automobile approaching in the motorcoach's travel lane, swerved to the right and applied the brakes. The motorcoach rotated clockwise, skidded, and struck the automobile broadside. (The automobile was, in fact, stopped at an intersection waiting to enter Route 57 from the west.) After colliding with the automobile, the motorcoach rolled over 270 degrees in a southwesterly direction, coming to rest on its right side on an embankment.

A 4-month-old infant, who was lying on her mother's lap in a plastic infant carrier before the overturn, sustained a fatal blow to the head during the crash. Her body and the infant carrier were found in a concrete drainage ditch near the motorcoach. The Safety Board determined that she and the carrier had been ejected through the window next to where her mother had been sitting (the left rear). The driver and the 25 remaining passengers were not ejected and sustained minor to serious injuries, resulting from secondary collisions with the armrests of the seats, the overhead luggage racks, and other interior fixtures of the motorcoach, during the rollover. The automobile driver sustained minor injuries.

The Safety Board concluded that had occupant restraints been available and used, the motorcoach's driver and passengers would have sustained fewer and less severe injuries. As a result of its investigation, on June 1, 1971, the Safety Board made the following recommendation to the FHWA:

> H-71-34
>
> Expand its rulemaking concerning Section 393.93 (seat belts) of the Motor Carrier Safety Regulations in Part 393 of Title 49, *Code of Federal Regulations*, to require in all interstate buses the installation of occupant restraints, active or passive, that conform to the MVSS 209.

The Board made the recommendation in a report it released on December 31, 1968, called *Interstate Bus-Auto Collision near Baker, California,* and made the recommendation again in *Chartered Interstate Bus Crash Interstate I-80S near Beaver Falls, Pennsylvania.* In the Board's view, a decision to make available suitable restraints that reduce injuries is not dependent upon a showing that all passengers would use the restraints, nor should the decision be affected by the fact that past bus passenger seat designs do not accommodate the lap-belt type of restraint.

The Safety Board also made the following recommendations:

H-71-35

NHTSA [should], in the development of its rulemaking related to Docket 2-11, *Bus Seats*, include the requirement for the installation of seat-belt assemblies as well as seat-belt anchorages for interstate buses.

H-71-36

The FHWA and NHTSA, in their rulemaking as recommended above, [should] include the requirement that occupants of interstate buses be advised, both by a "Fasten Seat Belt" illuminated sign and by notification by the driver, to fasten seat belts.

H-71-37

NHTSA should study the feasibility and practicality of a standard for passenger buses requiring that overhead surfaces, which include roof linings, moldings, parcel or luggage shelves, edges, and support hardware, be designed so as to reduce or prevent direct contact injuries in rollover and upset accidents, and that such areas resist separation or fracture of a type which would expose edges to passengers. Such protection is of particular importance in the absence of passenger restraints not currently required.

CASE 4

Date and Time	June 9, 1970, 4:40 p.m.
Date Report Adopted	December 30, 1970
Accident No.	NTSB/HAR-71-2
Location	Near Chantilly, Virginia
Operator	Greyhound Airport Service
Motorcoach Passenger Injuries	1 Fatal, 7 Nonfatal
Type of Crash	Head-On Collision With Automobile

A 1967 GMC Model PD4107 motorcoach on a regularly scheduled run was traveling in the eastbound median lane of the four-lane divided Dulles Airport access road when the driver saw an oncoming automobile traveling the wrong way in the motorcoach's traffic lane. The automobile driver was intoxicated. Although the automobile driver initiated an evasive maneuver to the left, the right front of the automobile collided with the right front of the motorcoach. After impact, the motorcoach continued eastbound and came to rest upright in the highway median, 278 feet from the point of impact.

The motorcoach had eight passengers, all of whom were seated in the first three rows. The motorcoach's right windshield popped out on impact, and the passenger in the right front seat was ejected through the windshield and fractured his spine and ribs as he struck the pavement. A passenger seated in the right second row was ejected forward down the center aisle and was restrained within the motorcoach by the driver at the front of the motorcoach. This passenger fractured his leg and died 20 days later from a blood clot that developed due to his injury. The driver, who was not using the lap belt, and the remaining six passengers sustained minor to moderate injuries. The driver of the automobile was killed.

As a result of its investigation, the Safety Board concluded:

> The presence and use of passenger restraints in the bus could have reduced the severity of injuries suffered in that vehicle. Such restraints would have contained the ejected passenger and the fatal passenger in their seats, reducing the severity of their injuries.

On March 29, 1971, the Safety Board recommended that:

<u>H-71-10</u>

> The FHWA expand its rulemaking concerning Section 393.33 (seat belts) of the Motor Carrier Safety Regulations in 49 CFR 393.33 by requiring in all buses the installation of occupant restraints, active or passive, that conform to MVSS 209 and will retain the passengers, as well as the driver, in their seats during collision and rollover.

The Board has recommended in two of its accident reports, *Interstate Bus-Auto Collision near Baker, California, March 7, 1968,* and *Chartered Interstate Bus Crash near*

Beaver Falls, Pennsylvania, December 26, 1968, that the FHWA consider its rulemaking and pending dockets on installing seat belts. The present regulation (Section 393.33) requires seat belts for drivers but not for passengers. In the Board's view, a decision to make available suitable restraints that would reduce injuries is not dependent upon a showing that all passengers would use the restraints, nor should the decision be affected by the fact that past bus passenger seat designs do not accommodate the lap belts. Retaining passengers in their seats during a crash is clearly desirable, as indicated by this case and others; and making restraints available is a first step.

The Safety Board also recommended that:

<u>H-71-11</u>

NHTSA, in the development of its rulemaking related to Docket 2-11, *Bus Seats*, include the requirement for the installation of seat-belt assemblies, as well as seat-belt anchorages, for intercity buses.

CASE 5

Date and Time	July 15, 1970, 1:55 p.m.
Date Report Adopted	September 8, 1971
Accident No.	NTSB/HAR-71-8
Location	Near New Smithville, Pennsylvania
Operator	Tudesco Bus Service
Motorcoach Passenger Injuries	7 Fatal, 46 Nonfatal
Type of Crash	Loss of Control, Run Off Road, and Rollover

A chartered 1967 GMC Model SDM5302 motorcoach carrying 53 school-age children and their counselors on a sightseeing trip was going westbound about 55 mph on Interstate Highway 78 (U.S. Route 22) during a rainstorm when the motorcoach crossed a section of highway that was covered with water. The motorcoach went out of control, rotated clockwise 180 degrees, traveled through a roadside cable guardrail, and vaulted down a 50-foot embankment, where it came to rest on its left side.

During the vault and overturn, 18 passengers were ejected from the side windows, the windshield, or the rear window; and 6 of the ejected passengers were pinned under the left side of the motorcoach when it came to rest. Four of the pinned passengers sustained fatal injuries. Two ejected passengers were not pinned but also sustained fatal injuries. After the motorcoach came to rest, the seventh fatally injured passenger escaped or was carried through the opening created when the rear window popped out. The driver and the remaining 46 passengers sustained minor to serious injuries.

The Safety Board concluded, "The availability and use of passenger restraints, such as seat belts, would probably have served to mitigate the degree of injury sustained by many passengers."

The Safety Board recommended that the FHWA:

H-71-87

> Take positive steps toward making available to the bus-traveling public convenient restraints against being ejected from their seats in a crash or rollover, such as are available to motorists and to airline passengers, so that bus passengers will not be denied their rightful opportunity to employ them whenever they so desire.

(Four previous Safety Board reports about interstate bus crashes had included a similar recommendation.)

CASE 6

Date and Time	October 10, 1971, 2:05 a.m.
Date Report Adopted	January 31, 1973
Accident No.	NTSB/HAR-73-1
Location	Near Marshfield, Missouri
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	4 Fatal, 33 Nonfatal
Type of Crash	Collision With Another Vehicle Followed by Motorcoach Overturn

A 1970 MCI Model MC-7 motorcoach on a regularly scheduled run was traveling westbound on U.S. 66 when it collided with the left side of a station wagon that was crosswise, either moving slowly forward or standing still, in the westbound lanes of the four-lane divided highway. The driver of the station wagon was intoxicated.

After the collision, the motorcoach rotated clockwise and skidded about 150 feet on the pavement, left the pavement, and, after crossing the shoulder, vaulted into a drainage ditch, where it rolled over 450 degrees and came to rest on its left side about 288 feet from the point of impact.

Four motorcoach passengers were fatally injured, including one of the five passengers ejected through the side windows and including the two passengers who were crushed by the collapse of the roof onto their seats. All the other 33 passengers and the driver sustained moderate to severe injuries.

The Safety Board concluded that had seat belts or some other form of restraint been available and used by the motorcoach passengers, the number of injuries and fatalities would have smaller. The Safety Board also concluded that the strength of the roof support structure of the "picture-window" type of bus was inadequate. The structure permitted gross downward and sideward deflection of the roof in a moderate rollover. The bus exhibited critical localized structural failure in side-window posts as a result of a design that permitted loads to be concentrated at points that could not compensate for the stress.

As a result of its investigation of this accident, the Safety Board recommended that:

H-73-1

> The FHWA and NHTSA institute appropriate rulemaking action to require all newly constructed interstate-type buses be equipped with approved occupant restraints, active or passive, for all seating positions in such buses.

The Board had recommended the same action in four other accident reports, which were released on December 31, 1968, March 19, 1970, June 1, 1971, and November 1, 1971, respectively. Such rulemaking would carry out the intent of the National Highway

Safety Bureau (later NHTSA) expressed in the "Preamble to Amendment to MVSS 208," Docket 2-13, Notice 3, on September 30, 1970, by the acting director:

> The extension of Standard No. 208 is based on the proposition that, so far as practicable, drivers and passengers in all types of vehicles should be afforded the means of protecting themselves from personal injury that seat belts provide . . .

The Safety Board also recommended that:

H-73-3

The Bureau of Motor Carrier Safety (BMCS), FHWA, review intercity bus design and the types of damage suffered in rollover accidents in an attempt to determine whether structural strength in the window areas may have been reduced in recent years in buses having very large side windows; and the BMCS prepare a rollover performance test, or other performance tests, for buses which can reveal the structural strength of buses in the areas stressed by rollover.

H-73-4

The manufacturers of intercity buses review their existing designs of buses having very large side windows to determine whether it is technically feasible to prevent critical localized structural failures and to increase the general strength of the window area of buses by the use of greater-strength window columns, by employing a larger number of continuous structural members through the window area, and by using smaller windows.

CASE 7

Date and Time	May 13, 1972, 5:35 a.m.
Date Report Adopted	October 25, 1973
Accident No.	NTSB/HAR-73-5
Location	Near Bean Station, Tennessee
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	12 Fatal, 15 Nonfatal
Type of Crash	Head-On Collision With Tractor-Semitrailer

A 1955 GMC Model PD4501 motorcoach on a regularly scheduled run was traveling eastbound on U.S. Route 11W, a two-lane highway, and started to pass an eastbound automobile. As the front of the motorcoach pulled even with the automobile's door, a westbound truck came into view around a curve. The motorcoach driver apparently made no attempt to return to the eastbound lane, and the motorcoach collided nearly head on with the truck.

The motorcoach driver was killed. At least three motorcoach passengers who sustained fatal injuries were ejected from the motorcoach before it came to rest. Two of them were found under the rear of the motorcoach's wreckage, and one was found west and south of the motorcoach's final rest position. The Safety Board was unable to determine with certainty how many other motorcoach passengers were ejected. The rescuers found four more dead passengers to the left and front of the motorcoach. A witness reported observing another motorcoach passenger spill out of the motorcoach after it came to a final rest. This passenger died en route to a hospital. Two survivors recalled "waking up" outside the motorcoach, but did not remember how they got there.

Approximately three-quarters of the seats on the motorcoach were displaced or twisted to some degree. The interior paneling on the roof and sidewalls was split, and sharp edges were exposed.

The Safety Board concluded that the installation of passenger restraints in the motorcoach and their use by the passengers would have prevented some ejections and reduced the severity of some of the injuries. The Safety Board also concluded that the fracturing and splitting of the interior panels and the failure of the seats contributed to the severity of the injuries.

As a result of its investigation of this crash, the Safety Board recommended that the BMCS of the FHWA:

H-73-42

Take positive action toward making available to bus passengers convenient restraints against being ejected from their seats in a crash or rollover.

A similar recommendation had been made in seven previous interstate bus crash reports issued by the Safety Board.

The Safety Board also recommended that NHTSA:

H-73-43

Revise part S7.1 of its proposed rulemaking—*Bus Passenger Seating and Crash Protection*, Docket 73-3; Notice 1, to require impact protection for interior panels located in and around bus passenger windows.

CASE 8

Date and Time	September 3, 1972, 2:20 a.m.
Date Report Adopted	February 23, 1973
Accident No.	NTSB/HAR-73-2
Location	Richmond, Virginia
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	3 Fatal, 39 Nonfatal
Type of Crash	Run Off Road and Overturn

A 1964 GMC Model 4106 motorcoach on a regularly scheduled run was traveling southbound on Interstate 95 when it traveled straight ahead in a right-hand curve and struck a median barrier rail. The motorcoach was then redirected across the southbound lanes and began a counterclockwise rotation. After leaving the roadway, the motorcoach struck a guardrail on the west side of the roadway and vaulted off the highway. After landing on its roof, the motorcoach slid backward down a steep embankment before coming to rest.

The Safety Board estimated that 20 passengers were probably ejected through the side windows during the final movement of the motorcoach. Two passengers who remained in the motorcoach were killed, as was one of the ejected passengers. The driver and the 39 surviving passengers were injured to varying degrees.

The Safety Board concluded that the availability and use of passenger seat belts would have reduced or eliminated the number of ejections, as well as the secondary impacts of passengers into overhead components and into other tumbling passengers. That the side windows were forced open by rollover-induced stresses contributed to the number of ejections.

As a result of its investigation of this crash, the Safety Board recommended that:

<u>H-73-6</u>

The BMCS of the FHWA maintain close surveillance over the performance of bus side windows in rollover crashes involving those buses which are required to meet the provisions of Section 393.61 of the Motor Carrier Safety Regulations, effective July 1, 1973, to determine as soon as possible whether these provisions will produce the degree of window retention contemplated in the Regulations and still permit effective escape of occupants via the side windows.

<u>H-73-7</u>

NHTSA and the BMCS take immediate action toward requiring the availability of seat restraints for passengers of buses in interstate commerce. First attention should be given to restraints in buses of new manufacture.

CASE 9

Date and Time	November 3, 1973, 9:00 p.m.
Date Report Adopted	December 13, 1974
Accident No.	NTSB/HAR-74-5
Location	Near Sacramento, California
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	12 Fatal, 33 Nonfatal
Type of Crash	Run Off Road and Collision With Bridge Column

A chartered 1953 GMC Model 4501SL motorcoach was traveling eastbound on I-880 near Sacramento, California, when it ran off the road to its left, overrode a guardrail, and collided with a bridge column. The preimpact speed of the motorcoach was estimated to be about 67 mph, and the 48-inch-diameter column penetrated through 21 feet of the center front of the 40-foot-long motorcoach. The driver and 12 passengers were killed; 22 passengers were hospitalized for moderate to critical injuries; 11 passengers were treated for minor injuries.

The motorcoach had a two-level passenger space; the front level had seats for 10 passengers (two double-seat rows left and three double-seat rows right of the center aisle). The rear level, which had a floor 28 inches higher than the front, had seats for 37 passengers (eight double-seat rows on each side of the center aisle, and a five-seat row in the rear).

The motorcoach had five windows on each side. The windows were hinged at the top, latched at the bottom, and designed as exits in an emergency. Immediately after the crash, some motorcoach windows were opened, and a passerby and the Sacramento police helped a few slightly injured passengers out of the motorcoach. Passengers reported that getting out of the motorcoach was difficult because it was dark, they were confused and jammed between seats, and it was 8 feet from the windowsill to the ground. They commented that the windows were heavy and that there was no way to hold them open.

Twelve people were killed; the Safety Board was able to determine where nine of them had been sitting. Five had had the aisle seats in the front level, one had had a window seat in the third row of the front level, one had been standing in the center aisle of the rear level, and one had had a window seat on the left side of the first row of the rear level. The ninth was the driver.

As a result of its investigation of this crash, the Safety Board recommended that the FHWA:

> <u>H-74-37</u>
>
> Establish regulations to facilitate evacuation of buses in an emergency. The incorporation of emergency lighting systems actuated through impact and entry for rescuers should be included in the regulation. Attention is called to the Board's investigation of the interstate bus accident in Baker, California, in 1968, in which it

> was recommended that "no new type buses go in to service which have not been tested to insure that all occupants can escape rapidly."

On February 15, 1973, NHTSA proposed a new motor vehicle safety standard requiring that all buses have passenger seats that are stronger, higher, and less hostile on impact. NHTSA proposed performance tests in three directions: an upward performance test of the seat's resistance to being torn away in a rollover, a rearward performance test of a seat's strength in a rear-end collision, and a forward test of a seat's strength in a frontal impact and its ability to deflect forward in a controlled manner that absorbs the crash energy. In addition, NHTSA proposed to require a restraining barrier in front of each front seat to protect passengers from being thrown into the driver, the windshield, or the door wells.[4]

On July 23, 1974, NHTSA rescinded its earlier proposal to promulgate a passenger seat standard applicable to all buses and, instead, proposed issuing a standard applicable only to school buses with a gross vehicle weight rating (GVWR) greater than 10,000 lbs. The notice stated:

> NHTSA has in fact determined that seating requirements for intercity and transit buses are not justified, based on benefit/cost studies of present seating performance in these buses. Injury statistics for intercity buses indicate that seating improvement would not reduce injuries substantially. Seat-belt usage surveys in intercity buses also indicate that a very low percentage of passengers would utilize seat belts if they were provided .... NHTSA has conducted conventional cost-benefit studies on school bus safety, but the normal valuation techniques evidently do not adequately reflect general public opinion on the importance of protecting children from death or injury. It is obvious from voluminous mail and congressional interest that society places a much higher value on its children than a conventional cost-benefit analysis would indicate. NHTSA has also concluded that only a small fraction of injuries resulting from school accidents appears in motor vehicle accident statistics. For these reasons, NHTSA is considering factors in addition to conventional cost-benefit studies to justify the imposition of passenger protection requirement in school buses.[5]

In its discussion of the Sacramento crash, the Safety Board stated:

> If the seats had met the standards . . . withdrawn . . . on July 30, 1974, the injuries suffered by passengers to the rear of row three would possibly have been less severe. However, whether more passengers (who sustained fatal injuries) would have survived in the new seats without seat belts cannot be determined. The higher seatback proposed in the withdrawn rule would have benefited the seat-belt user, because with seat belts, the proposed seats would probably have reduced lower and upper leg fractures and, in conjunction with the padded seatbacks, reduced head injuries and lacerations.

[4] *Federal Register*, Vol. 38, No. 35, February 22, 1973, pp. 4776-4779.

[5] *Federal Register*, Vol. 39, No. 147, July 30, 1974, pp. 27585-27589.

CASE 10

Date and Time	June 5, 1980, 12:47 a.m.
Date Report Adopted	January 21, 1981
Accident No.	NTSB/HAR-81-1
Location	Near Jasper, Arkansas
Operator	Central Texas Bus Lines, Inc.
Motorcoach Passenger Injuries	19 Fatal, 13 Nonfatal
Type of Crash	Loss of Control on Downgrade

A chartered 1967 Silver Eagle Model 01 motorcoach lost control as it descended a steep grade on State Route 7. The motorcoach ran off the roadway into a ditch on the right, overturned onto its right side, and began scraping along a hillside. About 120 feet from where the motorcoach first struck the hillside, the right-side window struck a large rock outcropping. The motorcoach then struck and mounted a 3-foot-high berm located at a concrete culvert headwall, and the driver, who was not using the lap belt, and two passengers were ejected through the windshield and killed.

The berm impact redirected the motorcoach diagonally to the left across the pavement and off the left pavement edge. Two more passengers were ejected, either through the windshield or the shattered right front side window. After leaving the pavement to the left, the motorcoach vaulted down into a gully and struck and either sheared off or uprooted several trees with trunk diameters ranging from 9 to 13 inches. Several more passengers were ejected through the windshield when the front of the motorcoach collided with a large boulder and the motorcoach came to rest upright.

Rescuers stated that several of the passengers who remained in the motorcoach were stacked up in the right front of the motorcoach.

CASE 11

Date and Time	November 16, 1980, 7:25 a.m.
Date Report Adopted	July 22, 1981
Accident No.	NTSB/HAR-81-4
Location	Luling, Texas
Operator	East Side Church of Christ
Motorcoach Passenger Injuries	2 Fatal, 35 Nonfatal
Type of Crash	Run Off Road and Overturn

A 1961 GMC Model PD-4106 motorcoach carrying a church choir was traveling south on U.S. Route 183. It was raining, and the pavement was wet. As the motorcoach attempted to negotiate a curve to the left, the rear tires lost traction. The motorcoach skidded across the opposing traffic lane and onto the northbound shoulder. The motorcoach then returned to and traveled across the roadway, spun 180 degrees, struck the side of a drainage ditch, and overturned onto its left side.

Two fatally injured passengers, who had been sitting together in the left third row, were ejected through a side window during the rollover and were found lying about 6 feet apart in the drainage ditch, in front of the front of the motorcoach.

CASE 12

Date and Time	February 18, 1981, 4:36 p.m.
Date Report Adopted	August 25, 1981
Accident No.	NTSB/HAR-81-6
Location	Near Triangle, Virginia
Operator	D & J Transportation Company
Motorcoach Passenger Injuries	10 Fatal, 13 Nonfatal
Type of Crash	Run Off Road, Collision With Bridge Parapet, Vault Into Creek

A 1959 GMC Model PD4104 intercity motorcoach on a regularly scheduled run for commuters going from Arlington to Stafford and Fredericksburg, Virginia, was traveling southbound in the median traffic lane of Interstate Highway 95 when it veered to the right and ran off the roadway. The right front of the motorcoach then struck and overrode a guardrail. After traveling 59 feet, the left front of the motorcoach struck the north parapet of the Chopawamsic Creek Bridge. The motorcoach vaulted off the bridge and came to rest on its right side in about 2 feet of water 25 feet below the highway.

The driver and 10 passengers were killed. All fatalities resulted from blunt trauma, including, in some cases, massive head and thoracic injuries. There were no ejections or drownings.

Although numerous seat legs tore loose from the floor, most of the seats remained in or near their precrash positions. Seat displacement was forward and slightly toward the right side of the vehicle, indicative of secondary impact as the passengers moved forward when the vehicle suddenly decelerated.

The least injured survivors told of moving from their seats and crouching or lying on the floor between the seats when they recognized that a crash was imminent. The Safety Board determined that their having left their seats helped them survive. They were subjected to less force because some of the force was absorbed by the processes of vehicle crush and seat displacement.

CASE 13

Date and Time	June 15, 1981, 8:00 p.m.
Date Report Adopted	September 29, 1981
Accident No.	NTSB/HAR-81-7
Location	Mt. McKinley National Park, Alaska
Operator	ARA Services, Inc.
Bus Passenger Injuries	5 Fatal, 25 Nonfatal
Type of Crash	Run Off Road and Overturn

A 1979 Blue Bird bus going eastbound on Denali Park Road ran off the right edge of the roadway at a very slow speed and rolled to its right down a hill. Each side of the bus had five windows, each 57 inches wide and 27 inches high. Each window included two separate panes, one of which could be opened by sliding it rearward. The windows were mounted in a single frame hinged at the top and latched at the bottom to the frame. By lifting up the bottom latch, each side window could be opened and used as an emergency exit. Each window also had a sensor that activated a buzzer to warn the driver that the window had been opened.

Twenty-five of the 30 passengers were ejected through the side windows before the bus came to rest, which it did after it had rolled 2 ¼ times down the hillside. Five of the ejected passengers were killed. The driver, who was restrained by a lap belt, was not injured. A driver instructor, who was sitting in the entrance stepwell when the bus left the roadway, was not ejected and sustained minor injuries.

The Safety Board concluded that the absence of passenger restraints permitted passengers to be thrown about within the vehicle and to be ejected from the vehicle as it rolled and contributed to the severity of the injuries and to the number of fatalities.

In its discussion of the crash, the Safety Board pointed out that since 1967, it had issued 13 recommendations to either the FHWA and/or NHTSA dealing with installing and using passenger restraints on intercity and/or school buses. In response, NHTSA has maintained that seat belts in such buses are not cost effective. NHTSA said that enforcing the use of seat belts would be a major problem and that passenger containment van be achieved through seat design and window design.

The Safety Board noted:

> In rollover accidents, side windows open as a direct result of cross-sectional body distortion, and major bending occurs at the side window posts (i.e. the weakest point) and the windows break and/or open. Smaller windows, or changes in the window locking design, will not prevent a window from opening in a rollover environment. Reducing window size small enough to prevent ejection conflicts with the need for a window opening large enough to be a good viewing area and also an emergency escape route. The availability and use of individual occupant restraints provides an answer to the problem of occupant ejection and also prevents the occupant from being tumbled within the bus.

CASE 14

Date and Time	November 30, 1983, 5:15 a.m.
Date Report Adopted	July 12, 1984
Accident No.	NTSB/HAR-84-4
Location	Livingston, Texas
Operator	Trailways Lines, Inc.
Motorcoach Passenger Injuries	6 Fatal, 5 Nonfatal
Type of Crash	Collision With Rear of Tractor-Semitrailer

A 1978 Silver Eagle motorcoach on a regularly scheduled run collided with the rear of a slower tractor flatbed-semitrailer combination in the right lane of southbound U.S. 59, about 5 miles north of Livingston, Texas. The motorcoach then veered across the left southbound lane, crashed through a bridge guardrail, and vaulted into a creek bank 26 feet below the bridge deck.

During the crash, four of the motorcoach passengers seated left of the center aisle were ejected through the left windows. Two of them died from massive head injuries, and one died of a broken neck. The fourth one survived but sustained the most serious injuries of any surviving passenger on the motorcoach, including rib fractures, a fractured left leg, a chest wall penetration, and a bruised right lung.

Three of the six passengers sitting on the right side of the motorcoach were fatally injured. One was ejected, either through the windshield or the left side windows. The other two were killed when they were thrown forward to the front of the motorcoach. One of the surviving passengers who was seated to the right of the aisle reported that he was awake before the crash and that he bent over in his seat and tucked his head down before the impact with the creek bank. The driver sustained a fractured jaw, fractured ribs, chest trauma, multiple lacerations, and abrasions to the eyes. He stated he was not wearing the lap belt.

The Safety Board concluded that had seat belts been available and had the passengers used them, the ejected passengers would not have been ejected and the passengers who remained inside the motorcoach would not have been as badly hurt. Had the driver used his seat belt, he would not have been less injured because he was sitting in the part of the motorcoach that bore the brunt of the impact with the creek bank.

CASE 15

Date and Time	July 18, 1984, 12:50 a.m.
Date Report Adopted	June 25, 1985
Accident No.	NTSB/HAR-85-4
Location	Near Cheyenne, Wyoming
Operator	Denver, Colorado Springs, and Pueblo Motorway, Inc.
Motorcoach Passenger Injuries	1 Fatal, 10 Nonfatal
Type of Crash	Rear-End Collision With Tractor-Semitrailer

A 1976 Silver Eagle motorcoach on a regularly scheduled run was traveling northbound in the right lane of Interstate Highway 25 about 3 miles south of Cheyenne, Wyoming, when it ran into the rear of a slower tractor flatbed-semitrailer loaded with pipe. The motorcoach, it was estimated, had been going 15 to 25 mph faster than the semitrailer. After the collision, the two vehicles remained together and traveled an additional 429 feet before coming to rest upright in the right lane of the northbound roadway.

The collision crushed the front lower half of the motorcoach about 3 feet rearward. The driver’s seat and both the left and right first-row seats were torn loose from their floor attachments.

The right front door was crushed by the collision and could not be opened. After the motorcoach came to rest, several passengers opened the emergency side windows and lowered themselves about 8 feet to the pavement. Rescue personnel later evacuated other surviving passengers through these windows.

None of the passengers were ejected. The driver, who sustained the most serious injuries of any surviving occupant, was pinned in the wreckage and was removed through an opening cut into the left side of the motorcoach. The passenger seated in the right first-row seat sustained fatal head injuries when he was projected forward and struck the semitrailer’s cargo of pipe, which intruded through the right windshield into the stepwell. The remaining passengers sustained minor to moderate injuries.

CASE 16

Date and Time	July 20, 1985, 8:15 p.m.
Date Report Adopted	January 21, 1987
Accident No.	NTSB/HAR-87-1/SUM
Location	Near Ackerly, Texas
Co-Operators	Three Church Groups
Motorcoach Passenger Injuries	4 Fatal, 37 Nonfatal
Type of Crash	Loss of Control, Run Off Road, and Overturn

A 1964 GMC Model PD4106 motorcoach co-owned and operated by three church groups was traveling in the right northbound lane of U.S. 87 in light rain when the motorcoach went out of control and skidded in a counterclockwise direction across the left northbound lane and about 130 feet across the grass median. As it traveled through the median, the motorcoach continued its counterclockwise rotation. It then slid sideways another 144 feet over both southbound lanes and off the roadway into a field, where it overturned 180 degrees and came to rest on its roof and facing west.

Three passengers seated next to windows on the right side of the motorcoach and one 3-year-old boy being held in his mother’s lap next to a window seat on the left side of the motorcoach were ejected through windows during the rollover. The four ejected passengers sustained fatal injuries when they were pinned under the motorcoach as it came to rest. The driver and 37 other passengers were injured.

CASE 17

Date and Time	August 25, 1985, 12:40 p.m.
Date Report Adopted	January 22, 1987
Accident No.	NTSB/HAR-87-1
Location	Frederick, Maryland
Operator	Baltimore Motor Motorcoach Company
Motorcoach Passenger Injuries	5 Fatal, 11 Nonfatal
Type of Crash	Loss of Control and Collision With Bridge Rail

A 1963 GMC Model PD4106 motorcoach on a regularly scheduled run was traveling westbound on Interstate 70 in light rain at a reported speed of 55 to 60 mph when it went out of control during a lane change and began swerving from side to side across the travel lanes and shoulders of the westbound highway as it approached the Monocacy River Bridge. When the motorcoach reached the bridge, it first collided with the left side of the reinforced concrete bridge rail. The motorcoach then rotated 360 degrees counterclockwise while rolling over. It became upright and came to rest facing westbound with its left front side against the left bridge rail.

The driver and 5 passengers were fatally injured; 11 other passengers sustained minor to serious injuries. During the collision sequence, the driver, who was not wearing the lap belt, and two of the passengers who were fatally injured were ejected through the opening made in the front of the motorcoach when it collided with the bridge rail. The other three fatally injured passengers, as well as seven survivors who sustained serious injuries, were ejected either through the front opening or the right side windows during the rotation and rollover.

The Safety Board concluded that the five fatally injured passengers sustained their fatal injuries in collisions with fixed objects outside the motorcoach. The Safety Board believed that the chances of survival would have been better if all occupants had remained inside the motorcoach during the accident sequence.

CASE 18

Date and Time	September 13, 1985, 5:20 p.m.
Date Report Adopted	January 21, 1987
Accident No.	NTSB/HAR-87-1/SUM
Location	Near Eureka Springs, Arkansas
Co-Operators	Ozark Christian Schools, Inc.
Motorcoach Passenger Injuries	4 Fatal, 19 Nonfatal
Type of Crash	Loss of Control on Downgrade, Run Off Road

A 1965 GMC Model PD-4106 motorcoach owned and operated by a church lost control while traveling southbound and descending a 7-percent grade on Arkansas State Route 23, a two-lane undivided highway. While traveling through a left curve, the motorcoach traveled over the opposing lane and struck a signpost to the left of the roadway. The motorcoach then veered across the roadway to the right, left the road, struck another signpost, and traveled about 150 feet down a wooded hillside until the front axle struck a large boulder. The motorcoach then rotated clockwise and overturned onto its right side before coming to rest.

The driver, all four passengers in the first row, and three of the four passengers in the second row were ejected, through either the windshield or the side windows. The driver and three of the seven passengers who were ejected were killed. Their fatal injuries included massive head trauma, fractured or crushed skulls, a fractured cervical spine, and an amputated left arm. The other four ejected passengers sustained minor to serious injuries.

In addition to the eight people who were ejected from the front of the motorcoach, a ninth person, who had the right window seat in the seventh row, was ejected through a side window. He also sustained fatal injuries, including massive internal injuries and an open skull fracture.

The motorcoach had seven rows of double seats on each side of the center aisle at the front, followed by an open area for storing choir robes. The rear had a 5-person bench, for a total of 33 fixed passenger seats. All of the seats were occupied at the time of the crash. Of the 24 passengers in installed seats who were not ejected, 12 sustained minor to serious injuries, and 12 were not injured.

In addition, five additional passengers were seated on folding chairs, two in the portion of the center aisle between the sixth and seventh rows, and three in the open area toward the rear. Three of these passengers sustained minor injuries, and two were not injured. Three more passengers were sitting on the floor in the open area toward the rear. None of them were injured.

CASE 19

Date and Time	May 30, 1986, 10:10 a.m.
Date Report Adopted	June 19, 1987
Accident No.	NTSB/HAR-87-4
Location	Near Walker, California
Operators	Starline Sightseeing Tours, Inc.
Motorcoach Passenger Injuries	21 Fatal, 19 Nonfatal
Type of Crash	Loss of Control, Run Off Road, and Rollover Into West Walker River

A chartered 1985 Neoplan Model N116-3 motorcoach was traveling southbound on U.S. Route 395 when it went out of control while negotiating an S-curve, veered left then right across the two-lane undivided roadway, and struck a rock retaining fence on the right shoulder. Continuing forward, the motorcoach crossed into the northbound lane, overturned and slid on its left side, rolled over as it traveled down an embankment, and came to rest upright in the West Walker River.

One surviving passenger reported that he was ejected through a window before the motorcoach entered the river. He did not recall whether the window was broken before or during his ejection. None of the passengers interviewed could recall how they sustained specific injuries. Many could not recall how they got out of the motorcoach.

Rescue units found eight fatally injured passengers in the motorcoach and on the nearby shore. Another 11 fatally injured people were found later downstream. Two of the critically injured passengers died several days after the crash.

Although 21 fatally injured passengers were autopsied, the could not be correlated to potential injury-causing mechanisms on the motorcoach because many passengers had sustained secondary injuries when they were ejected during the rollover either onto the river bank, which was laden with stones, or into the river, which was lined with sharp rocks. Postmortem examinations determined that 7 people died from drowning and 14 died from multiple traumatic injuries.

CASE 20

Date and Time	October 9, 1986, 7: 34 a.m.
Date Report Adopted	October 27, 1987
Accident No.	NTSB/HAR-87-6
Location	North Bergen, New Jersey
Operators	E. Vanderhoof and Sons, DeCamp Bus Lines
Bus Passenger Injuries	1 Fatal, 27 Nonfatal
Type of Crash	Collision With Rear of Automobile and Subsequent Sideswipe Collision With Commuter Bus

A chartered intercity 1970 Silver Eagle Model 05 bus traveling westbound on State Route 495 veered left into the adjacent traffic lane and struck the rear of an automobile. The bus then entered the eastbound contraflow lane and collided left-front-to-left-front with a 1972 GMC Type S8M5304A eastbound motorcoach loaded with commuters en route to New York City.

Of the 77 passengers in both buses, 26 sustained minor injuries, including multiple contusions, abrasions, and superficial lacerations of the face, head, and extremities.

On the commuter motorcoach, two passengers sustained serious injuries, including fractures of the ankle, face, fingers, hand, forearm, lower leg, and collarbone. One passenger sustained severe injuries: a subarachnoid hemorrhage and a cerebral concussion. One passenger, who had been in the left third-row window seat, was killed; he sustained comminuted fractures of the skull, a transection of the base of the skull, and a subdural hemorrhage.

All four passengers mentioned in the paragraph above had been seated in the first three rows. At impact they had been ejected from their seats and propelled forward into the front modesty panel, stanchion, and closed metal aisle gate. The Safety Board concluded that lap belts would probably have reduced the severity of the injuries of two of the three who sustained serious to severe injuries. The Safety Board also concluded that it was harder to predict the effect lap belts would have had on the other two because the belts would have restrained them in an area in which the charter bus intruded. Lap belts probably would not have lessened the injuries of the passengers and drivers who sustained minor injuries.

CASE 21

Date and Time	May 4, 1987, 1:45 p.m.
Date Report Adopted	February 2, 1988
Accident No.	NTSB/HAR-88-1
Location	Beaumont, Texas
Operator	Trailways Lines, Inc.
Motorcoach Passenger Injuries	5 Fatal, 17 Nonfatal
Type of Crash	Head-On Collision With Out-of-Control Tractor-Semitrailer

A 1977 Silver Eagle Model 05 motorcoach on a regularly scheduled run was traveling westbound in rain on Interstate Highway 10 when it was struck head on by a tractor-semitrailer that had been eastbound. The tractor-semitrailer had jackknifed on the wet pavement and crossed over the 32-foot-wide grass median strip separating the westbound and eastbound lanes of the highway. The semitrailer intruded into the motorcoach to the third row, and the driver and all 5 passengers in the first three right rows were fatally injured; 17 passengers sustained serious to minor injuries, and 6 passengers were not injured.

Four of the fatally injured passengers had been in the first two rows and were ejected through the front of the motorcoach. They were found 3 to 4 feet in front of the motorcoach. The bodies of the driver and the passenger in the third row were pinned in the wreckage.

Some of the seats of the fatally injured were torn from the floor and ejected during impact, and many of the seats in rows four through eight were removed by rescue personnel. It therefore could not be determined which seats in rows four through eight broke loose during the collision and which seats remained intact. The Safety Board, therefore, could not address the use of seat belts for these particular seats.

The Safety Board concluded that the fatally injured passengers would not have been saved by using seat belts. Although the installation and use of seat belts may have lessened the injuries of some of the surviving passengers, in general, the level of injury of those passengers who sustained minor or moderate injuries would probably have been the same because they would have sustained similar injuries from contact with the seatbacks, armrests, and side walls.

CASE 22

Date and Time	September 6, 1987, 5:00 a.m.
Date Report Adopted	May 24, 1988
Accident No.	NTSB/HAR-88-3
Location	Near Middletown, New Jersey
Operator	Academy Lines, Inc.
Motorcoach Passenger Injuries	1 Fatal, 32 Nonfatal
Type of Crash	Run Off Road, Collision With Bridge Rail, and Overturn

A 1982 Motor Motorcoach Industries, Inc., motorcoach on a regularly scheduled run was in the northbound "local" lanes on the New Jersey Garden State Parkway when it ran off the road to the left and collided with a bridge rail at about a 10-degree angle. A chain link fence was above the bridge rail; and as the motorcoach continued northbound in contact with the bridge rail, the fencing was torn from its mountings. Parts of the bridge rail and the fencing penetrated the windshield of the motorcoach to about the second row of seats. After traveling about 145 feet along the bridge rail, the motorcoach overturned onto its right side.

The driver sustained fatal injuries. The Safety Board concluded that his fatal injuries were attributable to the intrusion of the bridge rail, the fencing, and the steering wheel into his space. Although his body was found in the stepwell of the motorcoach and although he had not used his lap belt, using it would not have saved him.

The driver's 13-year-old son, who was in the right front row, also sustained fatal injuries. The Safety Board concluded that his fatal injuries were attributable to the intrusion of the railing and fencing. The use of a lap belt would not have mitigated his injuries.

Surviving passengers reported that they left the motorcoach through the left side emergency windows and/or the two emergency roof hatches. Thirty-two passengers sustained minor to moderate injuries.

The Safety Board determined that during the motorcoach's initial collision and its subsequent travel along the bridge rail the surviving passengers has been subjected only to low deceleration forces that were essentially along the longitudinal axis of the motorcoach; therefore the passengers were probably not ejected from their seats until the motorcoach overturned. The Safety Board also determined that the motorcoach had almost stopped when it overturned and that the lateral forces caused by the overturning were probably the highest g forces the passengers experienced during the accident sequence. The Safety Board determined that using lap belts would not have prevented the passengers from striking the seats in front of them, the walls, or other passengers in adjacent seats. If lap belts had been available and used, the passengers may have sustained different injuries, but injuries that probably would have been no less severe.

CASE 23

Date and Time	July 24, 1988, 7:35 a.m.
Accident No.	DCA-88-M-H006
Location	Near Camden, Alabama
Operator	Colonial Trailways
Motorcoach Passenger Injuries	1 Fatal, 30 Nonfatal
Type of Crash	Run Off Road and Overturn

A 1982 Eagle motorcoach on a scheduled run was traveling northbound on State Route 265 on a downgrade when it ran off the two-lane roadway to the right. The motorcoach returned to the roadway, and the rear of the vehicle rotated off the roadway to the left into a steep ditch. The motorcoach overturned onto its left side and came to rest facing east with its front partially blocking the southbound lane of the roadway.

Although all the windows on the left side of the motorcoach were displaced during the overturn, no passengers were ejected. During the overturn, the left side of the roof was displaced to the right and pushed down; the maximum displacement was near the longitudinal center of the motorcoach. One passenger seated in this area, in the window seat of the left sixth row, sustained fatal injuries consisting of fractured ribs, a fractured clavicle, and underlying lung injuries. The driver and 30 other passengers sustained minor to serious injuries.

CASE 24

Date and Time	February 18, 1989, 3:40 a.m.
Accident No.	FTW-89-H-FR02
Location	Near Falfurrias, Texas
Operator	Valley Transit Bus Company
Motorcoach Passenger Injuries	4 Fatal, 19 Nonfatal
Type of Crash	Loss of Control, Run Off Road, and Overturn

A 1988 TMC Model 96A3 motorcoach on a regularly scheduled run was traveling southbound on U.S. 281 in light rain at a driver-reported speed of about 55 mph when it skidded broadside across the northbound traffic lane, left the roadway, and struck a dirt embankment. After striking the embankment, the motorcoach overturned 450 degrees while rotating 180 degrees and came to rest on its right side facing north.

The motorcoach had seven emergency exit windows on each side. All but one of these windows, the one next to the left third row, were dislodged during the rotation and rollover.

In addition to the driver, 22 adults and a 5-year-old girl occupied the motorcoach. The driver, who was wearing his lap belt, sustained minor injuries. Three passengers believed that the side windows "popped out" of the motorcoach body, and at least 14 passengers were ejected through the side window openings. Two of them sustained fatal injuries, and the rest sustained minor to severe injuries.

One passenger, who had been sitting in the first row, reported he was ejected through the windshield. He sustained minor injuries. Of the passengers who remained inside the motorcoach, two were fatally injured.

CASE 25

Date and Time	May 18, 1990, 3:40 p.m.
Accident No.	FTW-90-F-H004
Location	Big Pine, California
Operator	Southwest Charter Lines
Motorcoach Passenger Injuries	2 Fatal, 43 Nonfatal
Type of Crash	Loss of Control and Run Off Road

A chartered 1987 TMC Model 102A3 motorcoach was westbound on California State Route 168 descending from the Westgard Pass when it lost control and ran off the roadway to the left, where its front and left side struck a rock and an earthen slope. When the left side struck the slope, a passenger sitting in the window seat on the left side in the seventh row was ejected and killed. All the windows on the left side were broken as a result of the impact with the slope, and the impact re-directed the motorcoach to the right. It crossed over the two-lane undivided roadway, traveled down a 7-foot embankment, and came to rest upright on the north roadside.

The driver reported that the ejected passenger was standing at the time of this impact. Another passenger seated in the left aisle seat in row two was critically injured and died 4 months later.[6] Nine other passengers stated they were ejected through either the side windows or the windshield. The rest of the surviving passengers sustained minor to critical injuries.

[6] Not considered a fatality on the FARS system.

CASE 26

Date and Time	February 2, 1991, 10:00 a.m.
Accident No.	NRH-91-FH-005
Location	Joliett, Pennsylvania
Operator	Leonard Lines, Inc.
Motorcoach Passenger Injuries	2 Fatal, 44 Nonfatal
Type of Crash	Loss of Control and Run Off Road

A 1990 Van Hool Model T-800 chartered motorcoach was traveling southbound on Pennsylvania State Route 209 descending a 5.4-percent grade when it swerved to the right as the driver reached to retrieve a thermos bottle that had rolled forward from the passenger seating area. A passenger in the right first row stated that after the motorcoach swerved to the right, the driver quickly sat up and turned the steering wheel hard to the left. The motorcoach veered left across the northbound lane of the two-lane roadway, crashed through a guard rail, and obliquely descended a 39-degree side slope, coming to rest upright and lodged between several trees 180 feet from where it left the roadway.

The driver stated that just before the motorcoach came to a stop, a passenger flew past him on his right and through the windshield. A passenger sitting in the first seat left of the aisle stated that as she reached down to pick up the thermos she was propelled forward, to the right, and into the aisle. The man seated opposite her on the right side stood up and pushed her back into her seat. The next thing she remembered was that she was lodged in the left windshield frame, half in and half out of the motorcoach, and that she then looked down in front of her and saw the man who had pushed her back into her seat lying on the ground outside the motorcoach. He had fatal injuries.

The driver’s seat, the tour guide’s seat in the stepwell, and the four seats in the first row had lap belts. Although the driver reported he was using his lap belt, several passengers reported that when the motorcoach came to rest he was in the stepwell. None of the passengers in the first row had used their belts.

Three additional passengers in the rear of the motorcoach were also ejected through the left rear side window. Immediately before the crash, one of them was kneeling on the aisle seat in front of the right-side restroom; another was standing in the aisle next to the last row in front of the restroom; and the third was seated in the window seat of the last row on the left side. One of these ejected passengers was killed, another sustained severe injuries, and the third sustained minor injuries. The driver and the remaining passengers sustained minor to serious injuries.

CASE 27

Date and Time	June 26, 1991, 1:50 p.m.
Date Adopted	March 13, 1992
Accident No.	NTSB/HAR-92-1
Location	Near Donegal, Pennsylvania
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	1 Fatal, 14 Nonfatal
Type of Crash	Run Off Road

A 1982 TMC Model MC-9 motorcoach on a regularly scheduled run was traveling eastbound on the Pennsylvania Turnpike when it ran off the right side of the roadway, traveled down a 100-foot embankment, and overturned onto its right side.

No one was ejected. A passenger seated in the second window seat on the right side sustained fatal blunt force injuries, including multiple rib fractures, a fractured sternum, and lacerations of the heart. The driver and 14 other passengers sustained broken bones, cuts, bruises, and abrasions.

CASE 28

Date and Time	January 24, 1992, 12:15 a.m.
Accident No.	NRH-92-F-H003
Location	Near South Bend, Indiana
Operator	United Limo, Inc.
Motorcoach Passenger Injuries	2 Fatal, 34 Nonfatal
Type of Crash	Run Off Road and Overturn

A chartered 1988 MCI motorcoach was traveling eastbound on the snow-covered Indiana Toll Road (Interstate Highway 80). The driver stated that he overtook a slower vehicle and tried to pass it on the left. He stated the vehicle ahead then moved to the left and he braked. Witnesses, however, stated there were no other vehicles immediately ahead of the motorcoach.

The motorcoach went out of control, rotated clockwise about 180 degrees, ran off the right side of the eastbound roadway, and slid down a 19-percent-grade embankment at an oblique angle. As it was descending the embankment, the motorcoach's left rear wheels struck a concrete culvert, and the motorcoach overturned onto its roof. The motorcoach came to rest inverted facing west at the base of the embankment, about 100 feet from where it left the roadway.

Two women were ejected through the windows next to them. Each woman had been sitting in a window seat on the left side of the motorcoach. Their seats, one in the 10th row and one in the 12th row, were among the rearmost seats on the motorcoach. Rescue personnel stated that both women were found under the motorcoach--one under the rear and one under the sixth window pillar on the left side. Both were killed; the cause of death was determined to be traumatic asphyxia. One of the other passengers sustained serious injuries, and the driver and the remaining passengers sustained minor to moderate injuries.

CASE 29

Date and Time	April 11, 1992, 4:45 p.m.
Accident No.	DCA-92-M-H002
Location	Near Schroon Lake, New York
Operator	Grey Line New York Tours
Motorcoach Passenger Injuries	2 Fatal, 29 Nonfatal
Type of Crash	Loss of Control and Overturn

A chartered 1990 MCI Model 10203 motorcoach was traveling southbound on Interstate 87 when it went out of control, ran off the right side of the roadway, and struck a cable barrier. After striking the barrier, the motorcoach returned to the roadway, rotated 180 degrees while crossing both southbound travel lanes, flipped over the median cable barrier, overturned 360 degrees, and came to rest upright, facing north, at the bottom of a steep embankment.

Both windshields and the destination sign panel broke out of the motorcoach during the crash sequence and were found at the top of the embankment. The rollover pushed the entire roof 2 to 5 inches downward. The passenger compartment had seven windows on each side; five windows were broken on the right side, and six windows were broken on the left side.

Six of the passengers were ejected through the side windows during the rollover. Two of them sustained fatal injuries.

CASE 30

Date and Time	July 26, 1992, 11:10 a.m.
Date Report Adopted	June 23, 1993
Accident No.	NTSB/HAR-93-2
Location	Vernon, New Jersey
Operator	Sensational Golden Sons Bus Service, Inc.
Motorcoach Passenger Injuries	6 Fatal, 37 Nonfatal
Type of Crash	Loss of Control on Downgrade

A 1972 MCI Model MC-7 chartered motorcoach lost control as it descended a steep grade on Sussex County Road 515, struck a car, overturned on its right side, slid and spun on its side, became upright, and struck another car before coming to rest. A fire ensued, burning the motorcoach and the second car, but no motorcoach passengers died in the fire.

After the motorcoach overturned and while it was sliding and spinning, 12 passengers in the first three rows were ejected through the windshield. Six of them sustained fatal injuries, including skull fractures, brain injuries, multiple internal injuries, and fractured extremities. The driver and the other 42 passengers sustained minor to critical injuries.

CASE 31

Date and Time	June 26, 1993, 4:40 p.m.
Accident No.	CRH-93-F-H040
Location	Near Springfield, Missouri
Operator	Cardinal Charters and Tours, Inc.
Motorcoach Passenger Injuries	1 Fatal, 46 Nonfatal
Type of Crash	Collision With Automobile, Run Off Road, and Overturn

A chartered 1987 Prevost motorcoach was traveling southbound on U.S. Highway 60 when it collided left-front-to-left-front with an automobile. The motorcoach then left the roadway to the right, skidded down a steep embankment, rolled onto its right side, and slid an additional 9 feet before coming to rest.

None of the motorcoach passengers were ejected. The driver and many of the passengers stated that the motorcoach had almost stopped when it rolled over. Most of the passengers stated that they had received their injuries from falling across the motorcoach and/or from having other passengers fall on top of them. Most of the 12 seriously injured passengers sustained arm, vertebra, and multiple rib fractures complicated by pneumothoraces. Several passengers sustained closed head injuries, including one injury that resulted in blindness. The fatally injured passenger was not autopsied, but the local county coroner believed she had sustained a crushed chest and a broken neck.

CASE 32

Date and Time	September 10, 1993, 7:10 a.m.
Accident No.	WRH-93-F-H054
Location	Near Phoenix, Arizona
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	0 Fatal, 33 Nonfatal
Type of Crash	Run Off Road and Overturn

A 1986 MCI Model 102A3 motorcoach on a regularly scheduled run was traveling eastbound on Interstate Highway 10 when it left the roadway to the right. The driver overcorrected, steering the motorcoach sharply to the left. The motorcoach then crossed both eastbound lanes and entered the median shoulder. The driver steered sharply to the right, causing the motorcoach to slide sideways and overturn onto its left side. It slid on its left side for about 140 feet and came to rest facing southeast and blocking both eastbound lanes.

Seven windows on each side of the motorcoach were emergency exit windows that were hinged at the top and latched at the bottom. The rollover displaced the roof of the motorcoach about 7 inches to the right; the left rear upper corner of the motorcoach sustained the most severe damage. Both windshields, the driver's left side window, and the rearmost left side window were broken. Four other windows on the left side were found open.

Three of the five most seriously injured passengers were sitting at the left rear of the motorcoach:

A 40-year-old man seated next to the left window in the 12th (rearmost) row sustained lacerations and contusions; both hands were severed. Later, doctors had to amputate both forearms.

A 15-year-old boy seated next to the left window in the 11th row sustained abrasions and contusions to the face and chest, a severe wound in the right hand, and a severed left arm.

A 61-year-old woman seated next to the left window in the 10th row sustained fractured ribs and pulmonary contusions.

Safety Board investigators determined that the left window spanning rows 11 and 12 opened before the left side of the motorcoach struck the roadway. During the rollover the man who would lose his hands was partially ejected; his hands and possibly his forearms were outside the window. As a result, the edge of the side of the motorcoach severed the man's hands when the motorcoach overturned and slid.

One of the other two most seriously injured passengers was a 58-year-old woman sitting at the window in the right fourth row. The aisle seat next to her was unoccupied. She sustained a ruptured spleen, cracked vertebrae, and a broken shoulder. The other most seriously injured passenger was sitting in the aisle seat in the 11th row on the right side. She sustained a broken neck and a fractured right hand. The driver and 28 of the passengers sustained minor to moderate injuries. Six of the passengers were not injured.

CASE 33

Date and Time	September 17, 1993, 2:08 p.m.
Accident No.	SRH-93-F-H042
Location	Winslow Township, New Jersey
Operator	Senior Care Centers of America, Inc.
Bus Passenger Injuries	6 Fatal, 8 Nonfatal
Type of Crash	Head-On Collision With Truck

A bus consisting of a National Motorcoach, Inc., body mounted on a 1985 Ford E-350 chassis was traveling westbound on Camden County Road 536 Spur at a witness-estimated speed of 30 to 35 mph when it collided head on with an eastbound truck that had crossed the center line of the undivided roadway.

The bus was manufactured with a GVWR of 11,000 pounds by Ford and 11,400 pounds by the second-stage manufacturer, National Coach, Inc. The bus had a wheelchair lift behind its door. Three rows of forward-facing two-passenger seats were behind the wheelchair lift. Behind the driver's seat was a two-passenger center-facing seat followed by three rows of forward-facing two-passenger seats. The bus could seat 14 passengers.

Each passenger seat had two vertical stanchions that were welded to brackets, forming seat legs shaped like an inverted "T." The seat legs were attached to the vehicle's floor by two bolts through the brackets. Each of the passenger seats had a lap belt. One end of each lap belt was bolted to a seat leg stanchion, and the other end was bolted to center of the seatframe below the cushion. All of the seats were occupied at the time of the collision, and it was reported that all of the passengers were using the lap belts.

At impact the stanchion-to-bracket welds of the right front, right center, and left center seats failed completely, and emergency responders reported that these seats with their belted occupants were found piled up at the right near the entrance door. The two passengers in the right front seat sustained fatal injuries, and the four passengers in the right center and left center seats sustained minor to serious injuries.

The stanchion-to-bracket welds for the left front and for both the left and right rear seats partially failed at the weld area connecting the aft portion of the stanchion to the floor bracket, and these seats were found tilted forward enough for the front edges of the seat cushions to touch the floor.

One of the passengers in the left front seat died the day after the crash, and the other passenger in this seat died 3 months later (December 21, 1993) from injuries sustained in the crash. The passengers in the left and right rear seats sustained moderate to serious injuries.

The stanchion-to-bracket welds for the center-facing seat did not fail. The passenger seated immediately behind the driver died 2 days after the crash, and the other passenger in this seat died 3 months after the crash (December 25, 1993). The driver died of his injuries a month after the crash (October 13, 1993).

CASE 34

Date and Time	January 29, 1994, 9:20 p.m.
Crash No.	WRH-94-F-HB02
Location	Near Pueblo, Colorado
Operator	El Paso-Los Angeles Limousine Express, Inc.
Motorcoach Passenger Injuries	1 Fatal, 8 Nonfatal
Type of Crash	Loss of Control, Run Off Road, and Overturn

A 1994 MCI model 102DL3 motorcoach on a regularly scheduled run was traveling southbound on Interstate Highway 25 on icy pavement when it went out of control, left the roadway, rotated 180 degrees, and rolled over onto its left side.

Each side of the passenger area had eight emergency exit windows that were made of shatterproof laminated glass. During the rollover, seven windows on the left were dislodged from their frames. Although the windows cracked when they separated from their frames, each remained in one piece. The windows on the right side of the motorcoach remained intact.

The driver was wearing his lap belt at the time of the crash and was not injured. During the rollover, two passengers were ejected through the left side windows and pinned under the motorcoach by the support posts between the windows. One of these passengers sustained fatal injuries, and the other sustained minor injuries. Rescue personnel removed a passenger from the motorcoach who was in the lavatory at the time of the crash. All of the eight other passengers left the motorcoach through the two emergency escape hatches on the roof.

CASE 35

Date and Time	April 23, 1994, 4:40 p.m.
Accident No.	DCA-94-MH-005
Location	Near Chestertown, New York
Operator	Best Transit Corporation
Bus Passenger Injuries	1 Fatal, 20 Nonfatal
Type of Crash	Run Off Road and Overturn

On April 23, 1994, about 4:40 p.m., a vehicle consisting of a 21-passenger Goshen Bus body mounted on a 1992 Ford chassis with a GVWR of 13,500 pounds was traveling southbound on Interstate Highway 87 near Chestertown, New York. The bus ran off the left side of the southbound roadway, rolled over 450 degrees, and came to rest on its left side facing west. The bus was in the median separating the north- and southbound lanes and was about 300 feet south of the point where it had left the roadway. Tire marks indicate that the bus left the roadway at a 7-degree left angle.

Each side of the bus had four windows that were each 3 feet wide and 3 feet high. Although the windows on the right side remained intact during the overturn, all four on the left side were broken out during the overturn. Based on the location of the glazing from the left windows, which was found about 80 feet north of the bus' final position, the left windows separated from the bus when it first rolled over 90 degrees to the left.

At the time of the crash, the bus was transporting 21 passengers; they were returning to New York City after visiting inmates at two penal institutions in Raybrook, New York. It is estimated that as many as 14 of the passengers were completely or partially ejected through the left windows during the rollover. One of the passengers who were completely ejected was killed, and the surviving passengers who were completely ejected sustained the most serious injuries.

CASE 36

Date and Time	July 23, 1995, 2:15 p.m.
Accident No.	NRH-95-MH-012
Location	Near Bolton Landing, New York
Operator	Bridges and Bridges Charter and Transit Service, Inc.
Motorcoach Passenger Injuries	1 Fatal, 30 Nonfatal
Type of Crash	Loss of Control, Run Off Road, and Overturn

A chartered 1990 Van Hool Model T-800 motorcoach lost control as it descended a steep grade on eastbound Warren County (New York) Route 11 approaching a “T” intersection with New York State Route 9N (SR 9N). Although the driver attempted to make a right turn at the intersection, the motorcoach side-slipped across both travel lanes of SR 9N, crashed through a box beam guardrail, plunged 150 feet down a steep embankment, overturned, and came to rest on its left side.

During the crash sequence the windshield separated from the motorcoach, and the left side windows shattered. The driver’s seat, the tour director’s seat (in the step well), the first-row seats on both sides of the center aisle, and the center position of the bench seat at the rear had lap belts. The driver stated he was restrained by his lap belt. The passenger in the tour director’s seat was not using the lap belt and was thrown into the step well. The front-row passengers on the left and a passenger who was standing in the center aisle near the first row were not restrained and were ejected through the windshield opening. The standee was killed. One passenger from the front row on the right was thrown forward into the entrance well.

Other passengers seated behind the first row were partially or completely ejected through the window openings on the left side.

A passenger in a fourth-row seat left of the center aisle was pinned under a tree branch; consequently she could not move her upper body. Her upper body, which was outside the motorcoach, was facing the window; and the lower part of her body was still inside the motorcoach. She sustained a fractured clavicle and chest and shoulder contusions.

A passenger in the fourth right row reported first being thrown around inside the motorcoach and then being ejected through a window. This passenger sustained eight fractured ribs and a fractured vertebra.

A passenger in the right sixth row was thrown out a side window, and a portion of the roof-mounted air conditioner landed on top of her. She sustained fractures of the spinal column, paraplegia, and chest trauma.

A passenger seated in the right eighth row was partially ejected and pinned under the motorcoach on her back with her knees against her chest and her feet dangling over her face. While she was pinned, EMTs gave her oxygen, suction, and IVs and monitored her heart. After the nonambulatory passengers were removed from the motorcoach, it was lifted off her with airbags. She was extricated about 1 to 1 ¼ hours after emergency responders arrived at the scene and was the last person evacuated. She sustained abdominal trauma and abrasions.

A passenger in the left ninth row was thrown through a side window, and her upper torso was pinned under the motorcoach. She sustained multiple traumas to the chest, head, and lower extremities.

A postcrash inspection of the lap belts of the left front row indicated that both buckles were missing. A postcrash inspection of the lap belts in the right front row indicated that the boots, or the covers for the tongues, were missing and that the web-sensitive retractors were jammed due to lack of clearance with the seat cushion. The lap belts of the four seats were, therefore. not functional before the crash.

CASE 37

Date and Time	October 14, 1995, 12:33 a.m.
Accident No.	CRH-96-F-H001
Location	Indianapolis, Indiana
Operator	Hammond Yellow Coach Lines (legal name of carrier may have been "Hammond Yellow and Checker Cab, Inc.")
Motorcoach Passenger Injuries	2 Fatal, 38 Nonfatal
Type of Crash	Run Off Road and Overturn

A chartered 1989 Eagle International Model 20 motorcoach exited from eastbound Interstate Highway 70 onto the Keystone Avenue exit ramp at an estimated speed of about 55 mph. The exit had an advisory maximum safe speed of 25 mph. The motorcoach yawed off the exit ramp, overturned onto its left side, and slid 50 feet.

Because the air conditioning on the motorcoach did not work, the side windows had been opened. Two passengers, a 9-year-old boy and a 30-year-old woman who was 6 months pregnant, were partially ejected through the side windows next to their seats and died of massive head injuries. The driver and the 38 remaining passengers sustained minor to serious injuries.

CASE 38

Date and Time	June 6, 1997, 6:30 p.m.
Accident No.	WRH-97-F-H005
Location	Near Albuquerque, New Mexico
Operator	Red Rock Limousine, Inc.
Motorcoach Passenger Injuries	1 Fatal, 35 Nonfatal
Type of Crash	Run Off Road

A chartered 1978 Prevost motorcoach was traveling southbound on Interstate Highway 25, 10 miles north of Albuquerque, New Mexico, when it drifted off the roadway to the right, rode up and over a guardrail, and struck the top 18 inches of a cement wall protecting a highway underpass. The impact forced the floor of the motorcoach about 2 feet upward at about the third row.

The impact ejected a male passenger from his first-row aisle seat, and his body hit and collapsed the right modesty panel separating the passenger compartment from the step well. He then continued forward and hit the right windshield, dislodging the glazing. Both he and the glazing fell about 15 feet to the surface of the dirt roadway passing underneath the Interstate Highway. He sustained serious injuries.

A woman seated in the right front window seat was also thrown from her seat and followed the man through the opening he had made in the windshield. Not being slowed by either the modesty panel or the windshield glazing, she was not only ejected, but thrown across the entire width of the roadway passing underneath the Interstate. She sustained fatal injuries.

The three passengers in the second and third rows on the right side were also ejected through the right windshield. They sustained moderate injuries.

The remaining 31 passengers sustained minor injuries. Several of the passengers broke the seatbacks of the seats in front of them as a result of the impact. The driver, who was not ejected, was not wearing his seat belt.

CASE 39

Date and Time	July 29, 1997, 7:15 a.m.
Accident No.	NRH-97-M-H010
Location	Near Stony Creek, Virginia
Operator	Rite-Way Transportation, Inc.
Motorcoach Passenger Injuries	1 Fatal, 32 Nonfatal
Type of Crash	Run Off Road Into River

A chartered 1985 TMC motorcoach was traveling northbound on Interstate Highway 95 when it left the roadway to the right, went through a fence, and vaulted over and through small trees into the Nottoway River, coming to rest on its left side in about 4 feet of water.

The fall into the river crushed the right front of the motorcoach back to the right front modesty panel, and a passenger who had been seated in the right first row was ejected. The passenger sustained visible head trauma and was found drowned near the driver's seat.

The impact pinned the driver's legs in the wreckage at the left front of the motorcoach, but his head was above the water; he was extricated by emergency responders and survived with serious injuries. The remaining 31 passengers, who sustained minor or no injuries, escaped from the partially submerged motorcoach through the windows on the right side.

CASE 40

Date and Time	September 13, 1997, 00:05 a.m.
Accident No.	WRH-97-F-H013
Location	Jonesboro, Arkansas
Operator	Greyhound Lines, Inc.
Motorcoach Passenger Injuries	1 Fatal, 6 Nonfatal
Type of Crash	Run Off Road

A 1993 MCI motorcoach on a scheduled run was traveling southbound on State Highway 226 when it failed to stop at a T-intersection stop sign controlling the entrance to U.S. Highway 49. The motorcoach swerved to the right as it entered the intersection, traveled across both lanes of U.S. 49, left the roadway, traveled southwest 26 feet through a ditch, and struck an earthen levee surrounding a rice field. The motorcoach then traveled up and over the levee and continued southwest another 100 feet, where it came to rest upright in the rice field. There were approximately 110 feet of tire marks through the intersection to the point where the motorcoach left the pavement.

The left front bumper and fender of the motorcoach buckled from striking the levee. The rest of the exterior damage, including superficial damage to the motorcoach's left side, was minor. The interior also sustained only minor damage.

Both of the motorcoach's windshields were found southeast of where the motorcoach came to rest. A passenger seated in the right front seat of the motorcoach before the crash was ejected through the windshield and was found in the rice field approximately 22 feet in front of the final position of the motorcoach. He sustained serious injuries and died after being transported to a local hospital. An inspection of the interior of the motorcoach disclosed no damage to the components along this passenger's ejection path.

The driver, who was using a lap belt, sustained minor injuries. Six other passengers also sustained minor injuries. One them, who was seated in an aisle seat on the right side of the motorcoach, reported that as result of the crash she was thrown down the center aisle to the front of the motorcoach. Two passengers were not injured.

Acronyms and Abbreviations

ABA	American Bus Association
AIS	Abbreviated Injury Scale
ATB	Articulated Total Body
BMCS	Bureau of Motor Carrier Safety
CFR	*Code of Federal Regulations*
CG	center of gravity
Commission	European Commission
DEKRA	Deutscher Kraftfahrzeug-Überwachungs Verein
DOT	Department of Transportation
EDGEN	Engineering Dynamics Corporation General Analysis Tool
EDSMAC4	Engineering Dynamics Corporation Simulation of Automobile Collisions
EDVDS	Engineering Dynamics Corporation Vehicle Dynamics Simulator
EDVSM	Engineering Dynamics Corporation Vehicle Simulation Model
EU	European Union
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSR	Federal Motor Carrier Safety Regulations
FMVSS	Federal Motor Vehicle Safety Standards
GATB	Graphical Articulated Total Body
GES	General Estimates System
GVWR	gross vehicle weight rating
HVE	Human Vehicle Environment
MADYMO	MAthematical DYnamical MOdels
MCI	Motor Coach Industries
MMUCC	Model Minimum Uniform Crash Criteria
m-smac	McHenry Simulation Model of Automobile Collisions
NAGHSR	National Association of Governors’ Highway Safety Representatives
NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
NSC	National Safety Council
UBOA	United Bus Owners of America
UNECE	United Nations Economic Commission for Europe
UNECER	United Nations Economic Commission for Europe Regulation
VIN	vehicle identification number