TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

Veridian
Calspan Operations
Buffalo, New York 14225

CALSPAN ON-SITE SCHOOL BUS CRASH INVESTIGATION
CALSPAN CASE NO. CA98-022
SCHOOL BUS CHASSIS: 1993 GMC VANDURA 3500
BODY: THOMAS BUILT MINOTOUR
LOCATION: TENNESSEE
CRASH DATE: MARCH, 1998

Contract No.
DTNH22-94-D-07058

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

DISCLAIMER

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

TECHNICAL REPORT STANDARD TITLE PAGE

<table>
<tr><td>1. Report No.
CA98-022</td><td>2. Government Accession No.</td><td>3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Calspan On-Site School Bus Crash Investigation
School Bus Chassis: 1993 GMC Vandura 3500
Body: Thomas Built Minotour
Location: Tennessee</td><td>5. Report Date:
October, 1998</td></tr>
<tr><td>6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Crash Research Section</td><td>8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Transportation Sciences
Crash Research Section
Calspan Operations
P.O. Box 400
Buffalo, New York 14225</td><td>10. Work Unit No.
1115 (8460-8469)</td></tr>
<tr><td>11. Contract or Grant No.
DTNH22-94-D-07058</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590</td><td>13. Type of Report and Period Covered
Technical Report
Crash Date: March, 1998</td></tr>
<tr><td>14. Sponsoring Agency Code</td></tr>
<tr><td colspan="3">15. Supplementary Notes
On-site investigation of a school bus crash that involved nine (9) restrained pre-school aged child passengers.</td></tr>
<tr><td colspan="3">16. Abstract
This on-site investigation focused on a 1993 GMC van based mini school bus that was involved in an off-set frontal crash with a 1993 GMC Sonoma pickup truck. The bus was occupied by nine (9) pre-school aged children who were restrained by lap belts and booster seats. The crash resulted in minor severity injuries to one child occupant and the restrained female bus driver. The driver of the pickup truck was not restrained and was fatally injured from his loading against the steering wheel assembly. Eight of the nine child passengers on board the bus were properly restrained by the lap belts. The remaining child was seated in a booster seat which was secured by the lap belt.</td></tr>
<tr><td colspan="2">17. Key Words
Off-set frontal crash
Mini school bus
Lap belts for the 20 passenger positions
Booster seats</td><td>18. Distribution Statement
General Public</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
15
22. Price</td></tr>
</table>

TABLE OF CONTENTS

CALSPAN ON-SITE SCHOOL BUS CRASH INVESTIGATION
CALSPAN CASE NO. CA98-022
SCHOOL BUS CHASSIS: 1993 GMC VANDURA 3500
BODY: THOMAS BUILT MINOTOUR
LOCATION: TENNESSEE
CRASH DATE: MARCH, 1998

BACKGROUND

This on-site investigation focused on a 1993 GMC van based mini school bus that was involved in an off-set frontal crash with a 1993 GMC Sonoma pickup truck **(Figure 1)**. The bus was occupied by nine (9) pre-school aged children who were restrained by lap belts and booster seats. The crash resulted in minor severity injuries to one child occupant and the restrained female bus driver. The driver of the pickup truck was not restrained and was fatally injured from his loading against the steering wheel assembly. Eight of the nine child passengers on board the bus were properly restrained by the lap belts. The remaining child was seated in a booster seat which was secured by the lap belt.

Figure 1. On-scene view of the crash site.

The crash notification was provided to NHTSA's Office of Safety Performance Standards and was forwarded to Calspan's Special Crash Investigation Team on Wednesday, March 25, 1998. Due to the police reported severity of the crash and the belted child passengers on board the bus, an on-site investigation was assigned. The Calspan SCI Team departed on the evening of the 25th and conducted the on-site investigation on Thursday and Friday, March 26-27, 1998.

SUMMARY

Crash Site

The crash occurred on a two lane state route in an urban area during daylight hours. The asphalt road surface was dry with a 3 percent grade, positive to the west. The travel lanes were bordered by narrow paved/stone shoulders with a ditch and an earth embankment bordering the south shoulder. A hillcrest was located 99 m (325') west of the crash site. The posted speed limit was 80 km/h (50 mph).

Pre-Crash

The driver of the school bus was traveling in a westerly direction and was transporting pre-school aged children to their residences following a half-day of pre-school special education. Initially the driver had 12 children on board the bus, however, she had completed three previous stops and discharged three children. All students on board the bus required special education for learning and physical disabilities. The students were restrained by manual lap belts and booster seats, therefore the driver was required to turn into the driveways of the residences to assist the child from the bus.

The driver was traveling in a westerly direction at an estimated speed of 48 km/h (30 mph). She noted that the posted speed limit changed from 48 to 80 km/h (30 to 50 mph) prior to the crash site. As she approached the next school bus stop at a residence that was located on the left side of the road, she began to decelerate. The driver stated that she stopped in the westbound travel lane to check for approaching eastbound traffic **(Figure 2)**. A hillcrest was located 99 m (325') west of the driveway. Due to the slope of the hillcrest and the height of the involved vehicles (driver's eye level), the line of sight was approximately 169 m (553') in both the east and westbound travel directions at the location of the residential driveway. Assuming a travel speed of 80 km/h (50 mph) for the GMC pickup truck, the vehicle was traveling at 22.4 m/sec (73.5 ft/sec). Therefore, if the driver of the bus was stopped prior to the left turn maneuver, she had approximately 7.5 seconds to view the pickup truck as it crested the hill and traveled the distance to impact. Based on this time/distance calculation, the driver either failed to detect the truck or attempted to "beat" the truck to her destination. It should be noted that the sun was not a factor in this crash as it was positioned at 10 o'clock with respect to the position of the bus. This was determined from an inspection of the crash scene at the reported time of the crash.

Figure 2. School bus driver's view of the approach of the GMC pick-up truck.

The driver of the 1993 GMC pickup truck had departed his place of employment that was located approximately 0.5 km (0.3 miles) west of impending crash site. He allegedly stopped at his work place to check with his supervisor on the availability of overtime work. He departed the facility and accelerated the vehicle in a easterly direction to the crash site **(Figure 3)**. The 26 year old male driver of the GMC pickup truck was not wearing the manual 3-point lap and shoulder belt system.

Figure 3. Pick-up truck driver's view at 169 m (553') west of POI.

The driver of the school bus stated that she had initially stopped in the westbound travel lane to check for approaching eastbound traffic prior to initiating a left turn into the private driveway. Although the driver checked for approaching traffic, she failed to detect the approaching eastbound pickup truck. It was unknown if the driver of the pickup truck had sufficient time to initiate avoidance action, or if the vehicle's braking system was in proper operating condition. There was no evidence of pre-crash braking. It should be noted that the Sonoma pickup truck was equipped with standard equipment rear anti-lock (ABS) brakes.

Crash

The left frontal area of the GMC pickup truck impacted the left center area of the left turning school bus as the bus turned approximately 30 degrees across the westbound travel lane. The impact occurred outboard of the pickup trucks left frame rail which resulted in engagement of the bus into the left front fender area of the pickup truck. Resultant directions of force were within the 11 o'clock sector for the pickup truck and within 1 o'clock for the school bus. The damage and trajectory algorithm of the WinSMASH program computed impact speeds of 69.3 km/h (43.0 mph) for the pickup truck and 22.2

km/h (13.8 mph) for the school bus. Respective velocity changes were computed at 52.6 km/h (32.7 mph) and 27.4 km/h (17.0 mph).

The momentum of the pickup truck rotated the bus approximately 122 degrees in a counterclockwise (CCW)direction and displaced its center of gravity approximately 2.1 m (7.0) rearward of its at-impact position. The bus came to rest diagonally across the eastbound travel lane, facing in an easterly direction with its left rear (dual) tires positioned on the yellow centerlines of the roadway. The pickup truck was displaced in a CCW direction as a result of the engagement with the bus and departed the south roadedge. The right rear quarter panel area of the pickup truck impacted an earth embankment as the vehicle entered the shallow ditch that was adjacent to the south shoulder. The impact redirected the vehicle in a clockwise direction as the right front tire came to rest in the mud at the base of the embankment. The pickup truck came to rest approximately 9.9 m (32.4') east of its at impact position, facing in a easterly direction parallel to the roadway. The final rest positions are documented in **Figure 4**.

Figure 4. Final rest position of the involved vehicles.

Post-Crash

As the school bus came to rest, the driver of the bus unbuckled her manual restraint system and immediately checked the condition of the pre-school aged children on board the bus. She then retrieved the emergency triangle markers to place at the crash scene. An off-duty school bus driver was traveling several hundred meters behind the school bus in her private vehicle and observed the crash from a distant vantage point. Due to the turning maneuver of the bus, this driver could not see the approaching GMC pickup truck. She parked her vehicle near the crash scene and approached the bus as the driver was exiting the vehicle with the markers. The bus driver handed the markers to the off-duty school bus driver, however, she did not place the markers at the scene. The off-duty driver used her cellular telephone to notify the school district's Transportation Supervisor of the crash scene. The local 911 operator was subsequently notified who dispatched the local Sheriff's Department, the investigating State Police officer, and an ambulance to the crash scene. The school bus driver retrieved the first-aid kit from the vehicle to treat a rear seated child occupant for an open facial laceration.

The crash was police reported to have occurred at 1135 hours. The Sheriff's Department received notification at 1141 hours and the first Deputy arrived at 1144 hours. The Investigating State Police officer arrived at 1150 hours, immediately after the arrival of the professional ambulance paramedics. The local fire department dispatched apparatus to the scene with their arrival occurring prior to the investigating officer's.

At rest, the right side of the school bus was exposed to the left side of the struck pickup truck and the injured driver. The bus driver and a passing motorist unbuckled the children from their respective seated positions and placed all the children on the left side of the bus to prevent their exposure to the injured driver and extrication activities. The off-duty bus driver subsequently proceeded to her residence and drove her assigned bus to the crash scene to provide bus transport for the students to a local hospital. Following the arrival of second school bus, the children were removed from the rear emergency door of the vehicle, placed in the bus and transported to the hospital where they were examined for possible injury. The child who sustained the facial laceration required two sutures to close the soft tissue injury. All children were released within three hours of the crash.

Emergency personnel used portable hydraulic equipment to open the left front door of the GMC pickup to extricate the driver. He was removed from the vehicle approximately 20 minutes following the arrival of the paramedics and transported by ambulance to a local hospital located 32 km (20 miles) north of the crash site. The driver expired within 5 minutes of arrival due to severe chest trauma. It was noted that the driver possibly sustained a closed head injury. He did sustain a large scalp laceration.

The driver of the school bus was subsequently transported by private vehicle to the local hospital where she was treated for multiple soft tissue injuries and released. Both vehicles sustained disabling damage which required towing from the scene.

SCHOOL BUS DATA

The involved school bus was a mini bus van chassis derivative with a 20 passenger bus body. The chassis was a 1993 GMC Vandura 3500 series that was identified by vehicle identification number (VIN) 2GDHG31J1P4 (production number deleted). The unit was manufactured on 2/93 and was registered with a gross vehicle weight rating of 4,536 kg (10,000 lb). The original wheelbase was 317.5 cm (125.0") with a drive train that consisted of a 6.2 liter diesel engine and a 4-speed automatic overdrive transmission.

The school bus body was manufactured by Thomas Built Buses and was identified as a Minotour model with a rated seating capacity of 20 passengers. The body was manufactured in Woodstock, Ontario, Canada, on 2/93, and was identified by body number 20143-12145M-26610-93-0416S-18. The school bus was purchased by the school district on October 3, 1994, as a new vehicle from Volunteer Bus Sales of Knoxville, TN. It should be noted that this county wide public school district maintains a fleet of 23 buses, including 20 full size (60 passenger) and 3 mini (20 passenger) buses.

The school bus was equipped with a 20.3 x 7.0 cm (8.0" x 2.75") parabolic mirror that was mounted on a tubular stalk over the left front corner area of the bus. This mirror provided the driver with a view across the frontal area of the bus. The mirror was mounted approximately 126.4 cm (49.75") above ground level. Other exterior mirrors included 25.6 x 18.4 cm (10.1" x 7.25") rectangular mirrors that were mounted to tubular frames adjacent to the A-pillars of the vehicle. The lower rectangular mirror was a shallow convex mirror while the upper mirror was a flat (plane) mirror. Both mirrors provided the driver with visibility along the respective sides of the bus.

Entrance to and egress from the bus was achieved through a double out-swinging right side door. The door panels were 30.5 cm (12.0') in width and 191.1 cm (75.25") in height. Both door panels were equipped with two tempered glass panels that were 21.3 cm (8.4") in width and 71.8 cm (28.25") in height. The door was operated by a manual linkage system with the handle positioned to the right of the driver's position. There was no damage to the door system.

The school bus was equipped with two hinged emergency doors; one mounted to the right side of the bus, rearward of the B-pillar area and the second mounted at the rear of the body. The right side door was 108.6 cm (42.75") in width and 158.8 cm (62.5") in height. A 48.3 x 73.3 cm (19.0 x 29.0") tempered glazing was mounted in the upper third area of the door. This door was hinged on the left side and opened toward the rear of the bus. The rear mounted emergency door was hinged at the right side (as viewed from the rear exterior). The door was 87.6 cm (34.5") in width and 137.2 cm (54.0") in height. The door contained two glazing panels, one at beltline height and the second at the level of the floor. There was no damage to the emergency doors or to the glazing. The rear door was utilized to remove the children form the bus.

In addition to the emergency doors, the Thomas bus body was equipped with a roof mounted emergency hatch which opened from the interior of the vehicle in a rearward direction. This hatch was closed and was not damaged. The side windows on each side of the bus between the second and third rows of seats were emergency exits. These emergency exit windows were hinged at the top with a lever latch located at the bottom of the units frames.

VEHICLE DAMAGE

Exterior - School Bus

The school bus sustained moderately severe frontal damage as a result of its off-set, frontal impact configuration with the 1993 GMC Sonoma pickup truck. The direct contact damage began 79.4 cm (31.25") right of center and extended 166.4 cm (65.5") to the left front bumper corner. A Collision Deformation Classification (CDC) of 01-FDEW-3 **(Figure 5)** was assigned to the frontal damage. The combined induced and direct contact damage (Field L) was 163.2 cm (64.25") which involved the entire frontal area. It should be noted that the direct contact damage was measured along the profile of the damage pattern while the Field L was documented parallel to the measurement reference line. Maximum crush was 51.7 cm (20.4") located at the left front corner of the front bumper **(Figure 6)**. The crush profile at bumper level was as follows: C1 = 51.7 cm (20.4"), C2 = 40.6 cm (16.0"), C3 = 31.6 cm (12.4"), C4 = 20.3 cm (8.0"), C5 = 4.8 cm (1.9"), C6 = 0 cm. The lateral component of the 1 o'clock impact force resulted in lateral displacement of the frontal structure. The left front bumper corner was displaced approximately 7.6 cm (3.0") left while the right corner was displaced approximately 15.2 cm (6.0").

Figure 5. Frontal damage to the school bus.

Figure 6. Profile view documenting the frontal crush profile.

The frontal area of the bus engaged against the left side surface of the pickup truck as the vehicles rotated from the impact forces. The center hood area of the bus contacted the upper left A-pillar of the pickup truck which resulted in deformation to the center hood face.

The aluminum school bus body was blended into the body of the van based cut-a-way chassis with a fiberglass filler panel that surrounded the windshield header and the right door area of the bus. Due to the structural crush at the left corner area of the Vandura chassis and the left lateral displacement of the frontal structure, partial separation of the fiberglass panels occurred. The fiberglass roof panel at the header fractured surrounding the nine No. 10 gauge x 15.9 cm (0.625") coarse thread sheetmetal screws. The cab area of the bus was displaced laterally left which resulted in minimal separation at the left A-pillar/header juncture. The full width of the filler panel at the header separated to a maximum of 8.2 cm (3.25") at the right side juncture point. In addition, the adjoining filler panel between the OEM width of the cab and the extended width of the bus body was fractured at the height of the right roof side rail. The fracture line was horizontal, however, the separation was not sufficient for occupant ejection. The separations are documented in **Figure 7**.

Figure 7. Fracture/separation of the fiberglass filler panels.

The riveted body of the school bus remained intact with no evidence of body panel separation. The floor was slightly bowed at the top of the stairwell with no separation noted. All window glazing remained intact with no cracks occurring to the laminated windshield. The left front door was jammed closed due to the structural deformation at the left front corner. The left wheelbase was reduced in length by 22.6 cm (8.9") while the right wheelbase was elongated by 1.9 cm (0.75").

Exterior - GMC Pickup Truck

The 1993 GMC pickup truck sustained severe damage which resulted from the head-on crash with the bus and minor secondary damage from contact with an earth embankment as the vehicle came to rest. The initial impact damage occurred at the left frontal area of the pickup truck. The direct contact damage began 30.5 cm (12.0") left of center and extended 45.7 cm (18.0") to the left corner. The primary impact occurred outboard of the left frame rail which allowed the bus to engage against the sheet metal radiator support panel, left front fender, and the hood face. Two crush profiles were documented for the frontal structure; bumper level and the upper radiator support level. The residual crush profile at bumper level was as follows: C1 = 52.1 cm (20.5"), C2 = 26.7 cm (10.5"), C3 = 15.0 cm (5.9"), C4 = 7.6 cm (3.0"), C5 = 0.2 cm (0.1"), C6 = 0 cm. The upper radiator support profile was as follows: C1 = 78.7 cm (31.0"), C2 = 65.5 cm (25.8"), C3 = 33.3 cm (13.1"), C4 = 10.8 cm (4.25"), C5 = 5.1 cm (2.0"), C6 = 3.5 cm (1.4"). These profiles were average for the SMASH reconstruction output. In addition, two independent measurements were documented to identify the severity of damage to the Sonoma pickup

Figure 8. Frontal damage to the GMC pickup truck.

truck. These included a maximum crush value of 103.5 cm (40.75") at the left corner of the hood face and a rear displacement value of 29.8 cm (11.75") at the mid left upper A-pillar. The A-pillar deformation resulted from contact against the hood of the school bus. The CDC for the initial damage profile was 12-FLEK-5, utilizing the K conversion rule of CDC. The secondary engagement CDC for the "K conversion"was 10-LYAW-4. The damage profile is documented in **Figure 8**.

The right rear quarter panel area of the pickup truck was damaged as a result of contact with the earth embankment as the vehicle was deflected off-road to final rest. The damage occurred rearward of the right rear axle position and involved approximately 10 cm (4") of sheet metal crush.

SCHOOL BUS INTERIOR

The interior of the bus consisted of the stairwell, the driver's compartment **(Figure 9)**, and passenger area. The stairwell consisted of three stair threads and two risers. A stainless steel handrail was mounted to the padded crash panel and the stringer area of the stairwell. The hand rail was formed with a 90 degree radius at lower attachment point and an angled end at the upper attachment point. This configuration would not allow a drawstring to snag at the lower attachment point.

Figure 9. Overall frontal view of the driver's compartment.

The driver's seat was a box base bucket seat with a rigid seat back. The adjustable seat track was positioned 3.8 cm (1.5") forward of the full rearward track position. A 3-point lap and shoulder belt system was mounted to the left B-pillar area of the vehicle. The belt system consisted of two independent webbings that were affixed to a common latchplate. The retractor was an inertia activated locking retractor that was mounted to the lower aspect of the pillar. The upper anchorage was not adjustable. Loading evidence on the belt system consisted of an elongated D-ring transfer that began 39.4 cm (15.5") above the belt retractor stop button and extended 28.2 cm (11.1") upward. The transfer extended the full width of the shoulder belt webbing. The belt system was manufactured by Bendix Safety Restraints Group as Model No. 9011. The date of manufacturer was 08/3/93 with a GM No. Of 15681625.

The OEM rear view mirror was mounted on the windshield and was not damaged or displaced during the crash. A large interior mirror was mounted to the front bulkhead of the bus which provided the driver with a view of the passenger compartment of the vehicle. The mirror was 43.8 cm (17.25") horizontally and 18.0 cm (7.1") vertically **(Figure 10)**.

Figure 10. D-ring transfer on shoulder belt webbing.

The bus was equipped with a cellular telephone that was mounted on a stalk to the center mid instrument panel. The telephone was utilized for communication between the driver and the bus garage/administration. A remote microphone was mounted on the outboard aspect of the left sunvisor for hands-free operation. The phone was hard-wired in the bus.

The passenger compartment area of the bus was designed to seat 20 passengers **(Figure 11)**. The seating configuration consisted of four rows of high-back padded seats with three positions on the left side and two passenger positions on the right. The left side seat cushions were 97.8 cm (38.5") in width and 38.1 cm (15.0") in depth. The seat backs extended 65.4 cm (25.75") above the seat cushions. Padded crash barriers were positioned forward of the first row of seats to provide crash protection against frontal impacts. The left side seats were supported on a rail at the outboard wall and secured with two 9 mm (3/8") diameter Grade 5 bolts. The inboard aspect of the seat was supported on two legs that were secured to the floor of the bus. Each leg consisted of two supports welded to a 10.2 x 15.2 cm (4.0 x 6.0") plate that was bolted to the floor with four 8 mm (5/16") diameter Grade 5 bolts. A diagonal cross strut was welded longitudinally between the front and rear leg supports.

Figure 11. Overall view of the seating capacity of the bus.

The right side seats of the bus were designed as two passenger seats. The first seat on the right side was adjacent to the emergency door and was narrower in width than the three rear seats to allow for egress from the bus through the emergency door. This seat cushion was 64.8 cm (25.5") in width and 38.1 cm (15.0") in depth. The remaining right side seats maintained the same depth, however, they were 76.2 cm (30.0") in width. The right side seat backs were 64.8 cm (25.5") in height from the top of the seat cushion. The right front passenger seat was covered in a green vinyl while the remaining seats were covered in a gray vinyl fabric.

The right front seat was supported by four legs that were bolted to the floor. Each leg was terminated with a mounting plate and secured with two 9 mm (3/8") diameter, Grade 5 bolts. The second, third, and fourth rows of right seats were attached to the wall mounted rail with two 8 mm (5/16") diameter Grade 5 bolts. The inboard aspect of the seats were supported by two legs with a mounting plate that was secured with two 8 mm (5/16") diameter bolts for each leg. All seats remained securely fastened to the floor of the bus and there was no buckling/damage to the floor system.

MANUAL RESTRAINT SYSTEMS - SCHOOL BUS

The involved school bus was primarily used to transport pre-school aged children, therefore Tennessee law requires seat belts for all designated seated positions. This bus was equipped with lap belts for the 20 passenger positions. The belts were installed in the bus by the manufacturer prior to the districts purchase of the vehicle. All belt systems were supplied by Beam's Seat Belts, Inc., of Oklahoma City, OK. The buckles were stamped as Made in Taiwan and identified as Model Nos. P8 301D. The latchplates were equipped with a sliding cinch bar and were stamped with Beam's U.S. Patent No. 2.8 03 .864.

Each seat was equipped with color coded lap belts to aid in the identification of the appropriate component for each position. The left side three passenger seats were equipped with black belt webbings for the outboard positions, red center belt webbings, and beige inboard mounted webbings **(Figure 12)**. The right side seats were equipped with black outboard bets and red inboard belt systems

(Figure 13). The belt systems were bolted to a 6.4 cm (2.5") wide plate that was 3.2 mm (1/8") in thickness that was welded across the full width of the seat frame. The seat belt attachment bolts were Grade 5, 11 mm (7/16") in diameter x 2.5 cm (1.0") in length, and were secured with a self locking nut. The right side belt systems were bolted with 11 mm (7/16") diameter Grade 5 bolts to brackets welded to the legs of the seat frames.

Figure 12. Left side belt configuration.

Figure 13. Right side belt configuration.

Figure 14. Evenflow booster seat.

The total length of the buckle webbing (inclusive of buckle) was approximately 27.9 cm (11.0") while the length of the latchplate webbing was 104.1 cm (41.0"). The belt systems were configured with the buckles positioned on the outboard and isle sides of the seat and on the inboard aspect for the center seat position. These systems could securely restrain a small child and extend to restrain a booster/child safety seat.

In addition to the belt systems, the school bus was equipped with six booster seats to accommodate small children assigned to this vehicle's route. The booster seats were removed from the vehicle and placed in the replacement bus following the crash. There were two types of booster seats on board the bus at the time of the crash, however, only one was in use. The booster seats were manufactured by Evenflo and Cosco. The Evenflo booster seats were identified as a Sight-Seer model **(Figure 14)**, however, the labeling was worn away from the plastic shell. This seat consisted of a plastic shell with a pivoting abdominal restraint shield. The U-shaped shield offered a contoured restraint for the child occupant and a channel to position the belt webbing. The shield pivoted on a tubular rod at the left side of the restraint. A label which identified the placement of the shoulder belt webbing was dated 12/91, therefore the booster seat was approximately six years old. This seat was gray in color with a gray fabric material over a 1.3 cm (0.5") foam padding on the seat base and shield.

The Cosco booster seat was identified as an Explorer with a Model No. of 02399EMF. The restraint was manufactured on 10/10/95. This seat was similar in design to the Evenflo booster seat with a pivoting restraint shield hinged at the left side of the shell. The seat is green in color with a foam padding under the fabric covering on the seat base and shield. The lap belt engages across the full width of the shell to restrain the child and seat. The seat was designed for occupant weights of 14-27 kg (30-60 lbs.). The driver preferred to use the Evenflo booster seat (most user friendly). She noted that she placed unused booster seats behind the fourth row seats.

HUMAN DEMOGRAPHICS

School Bus Driver

Age/Sex:	48 year old female
Height:	168.9 cm (66.5")
Weight:	104.3 kg (230.0 lb)
Manual Restraint Usage:	3-point lap and shoulder belt
Usage Source:	Vehicle inspection, driver interview
Eyeware:	Corrective contact lenses for myopia, sunglasses resting on top of head
Mode of Transport From Scene:	Private vehicle to hospital
Type of Medical Treatment:	Treated and released for multiple soft tissue injuries

School Bus Driver History

The 48 year old female bus driver held a current Class B Tennessee driver's license (expiration 08/14/99) which allowed her to drive the mini buses. (A Commercial Driver's License (CDL) is required to drive the full-size school buses.) She was hired as a part-time school bus driver in the summer of 1985 and has been an active driver for the past 13 years. Her driving record was reported as flawless by the Transportation Supervisor, therefore she has not been charged with traffic violations or involved in previous crashes. She has completed all required training and had participated in the four-hour update training at the start of the school year in August, 1997. In addition, the Supervisor noted that district's insurance carrier provided a skills training to all drivers during August, 97. Her medical physical was updated and approved in August, 97.

The driver was required to wear prescription contact lenses for myopia. She noted that she had an eye examination in January, 1998, however, her prescription did not change from the previous examination. She routinely wore non-prescription sunglasses while driving and noted that the sunglasses were placed on top of her head and were not worn over her eyes at the time of the crash.

The driver had been assigned to this special education pre-school bus route for approximately five years. Although, the route changes on an annual basis, the procedures have remained constant. Her daily routes involve the pickup and discharge of two groups of pre-school age children. The first route begins at 0830 hours with the pickup of 13 children ranging in ages from 3-5 years. These children are picked up in their driveways (space permitting) and placed in the seats by the driver. She properly secures the children with the manual lap belts and positions the required children in the booster seats and secures the seats with the lap belts. The driver must park the bus and turn off the ignition and exit her seat to complete this task. The students are then transported to the elementary school for a one-half day program. This is the group of children that were involved in this crash.

The second route begins at 1030 hours by picking up the afternoon group of children. The same procedures as above are followed and these children are transported to the elementary school.

The early morning students are discharged from the school activities and escorted to the school bus by their teacher who assists the driver in placing the children on the bus and properly securing the children into the booster seats and lap belt systems. This task was also assisted by two school aids. Both the driver and teacher stated that all back packs are removed and placed on the floor of the bus to ensure a proper fit of the lap belt. They place their hands between the child's body and the lap belt to check for a snug adjustment of the belt webbing. The bus departs the school at 1130 hours for the driver's third bus run of the morning. The driver's fourth bus route involved the return of the students who arrived at the school for the afternoon session at 1130 hours.

The Transportation Supervisor stated that this school bus driver drove the greatest distance of all bus driver's for the district. Her average daily routes covered approximately 161 km (100 miles). She was extremely familiar with the area of the crash as her assigned routes result in her passing the crash scene six times daily, traveling in both directions.

School Bus Driver Medication

The driver voluntarily admitted that she was taking the prescription medication *Synthyroid*. In addition, the driver was taking an over-the-counter nasal decongestant (CVS brand non-drowsy formula). On the morning of the crash, prior to the driver reporting for work, she took two of the decongestants and one pill of the *Synthyroid*. The driver noted that the medication did not affect her ability to drive or impair her daily activities.

Following the crash, the investigating officer requested the driver to submit to a blood test to screen for both alcohol and drugs. The results of the toxicology tests were negative for alcohol and drugs.

Driver Injuries

Injury	*Injury Severity (AIS-90)*	*Injury Mechanism*
+ Small laceration of left 5th finger	Minor (790602.1,2)	Left door panel (probable, no contact evidence)
+ Contusion of the posterior aspect of the right upper arm	Minor (790402.1,1)	Right side door lever handle
+ Superficial laceration over the dorsal aspect of the right foot	Minor (890602.1,1)	Foot controls
+ Contusion over the right hip	Minor (890402.1,1)	Lap belt webbing

Injury	*Injury Severity (AIS-90)*	*Injury Mechanism*
* Chest contusion with soreness over the left anterior ribs and sternum	Minor (490402.12)	Shoulder belt webbing

+Source - Driver interview
**** Source - Medical records***

Driver Kinematics

The driver of the bus was seated in a normal upright driving posture with the manual seat track adjusted to a rear track position. She was properly restrained by the manual 3-point lap and shoulder belt system. Belt usage was supported by a D-ring loading transfer on the shoulder belt webbing and injury sustained by the driver from loading the belt webbing. The latchplate yielded routine wear marks which supported frequent usage of the system.

At impact, the driver responded to the 01 o'clock impact force by initiating a trajectory that was forward and to her right. During this trajectory, the bus was rotated rapidly in a counterclockwise direction. The driver loaded the manual belt webbing which resulted in a contusion across her right hip and soreness over the sternum and the left anterior ribs. Her loading force against the belt webbing produced an elongated D-ring transfer on the belt webbing that began 39.4 cm (15.5") above the stop button on the webbing and extended 28.2 cm (11.1") upward across the full width of the webbing **(Figure 15)**.

Figure 15. D-ring transfer on the shoulder belt webbing.

The belt spool-out and the compression of the shoulder belt webbing against the driver, resulted in her loading against the steering wheel rim. Although there was no deformation of the steering wheel rim and/or spokes, the energy absorbing steering column compressed minimally. The left shear capsule was compressed 0.6 cm (0.25") while the right was stroked 0.9 cm (0.375").

The driver's hands probably separated from the steering wheel rim due to the impact force and the rapid rotation of the vehicle. Her left hand probably impacted the left door panel which resulted in a small laceration of the left 5th finger. Her right arm contacted the mid mounted right side door lever assembly which resulted in a contusion over the posterior aspect of the upper arm. There was no contact evidence to support these contact points. The dorsal aspect of the driver's right foot contacted the foot controls which resulted in a superficial laceration of the foot. None of the lacerations required sutures.

Immediately following the crash, the driver unbuckled her manual restraint system and checked on the status of the children on board the bus. She assisted with their care and removal from the vehicle. The driver was subsequently transported to a local hospital by a private automobile where she was treated for her injuries and x-rayed for possible skeletal fractures. The x-rays were negative and the driver was released following treatment.

Child Passenger Demographics/Seating Configuration

Row 1

			Center Isle		

Row 2

5 year old male, 91 cm (36"), 18 kg (40 lb), lap belted, not injured				5 year old male, lap belted, not injured	5 year old female, 107 cm (42"), 17 kg (38 lb), lap belted, contusion posterior scalp

Row 3

3 year old female, 95.3 cm , 14.5 kg, Evenflo booster seat/lap belted, not injured					4 year old male, lap belted, not injured

Row 4

4 year old female, 107 cm (42"), 17 kg (38 lb), lap belted, left facial laceration	5 year old male, 91 cm (36"), 18 kg (40 lb), lap belted, not injured	5 year old male, 104 cm (41"), 19 kg (42 lb), lap belted, not injured		5 year old female, 107 cm (42"), 23 kg (50 lb), lap belted, not injured	

Row 4, Left Side Child Occupant Injuries

Injury	*Injury Severity (AIS 90)*	*Injury Mechanism*
2 cm laceration left lateral face adjacent to the eye, required 2 sutures	Minor (290602.1,2)	Left side window frame
Abrasion over the left distal fibula	Minor (890202.12)	Forward seat back support/side wall of bus
Abrasion left ankle	Minor (890202.12)	Forward seat back support/side wall of bus

Child Passenger Kinematics

The children were properly seated in the school bus and were restrained by the manual lap belt systems. Of the nine children on board the bus, one was seated in a booster seat. This child was a 3 year old positioned in the third row in the outboard position, adjacent to the window. She was seated in the Evenflo Sight-Seer booster seat with the lap belt properly positioned across the restraint shield. There was no evidence of loading or damage to the shell of the booster seat. In addition, there was no evidence of loading on the manual belt systems for the identified seated positions.

The 5 year old child occupant seated in the second seat, right side outboard position, sustained a posterior scalp contusion from a possible rebound into the side surface of the bus. There was no evidence of contact within the seated area to support a specific injury mechanism.

The 4 year old female passenger seated in the fourth row, left outboard position was restrained by the manual lap belt system **(Figure 16)**. In response to the frontal impact force, she impacted the left side of her face on the base of the window frame at the side wall of the bus. As a result of the contact, the child sustained a 2 cm laceration of the left face adjacent to the left eye, extending onto the cheek. This laceration required 2 sutures which were removed four days following the crash. This child also sustained abrasions over the left ankle and the left distal fibula that resulted from probable contact with the front seat back support and/or the left side wall of the bus. Her mother reported that she had a slight discharge from the left ear, however, the treating physician ruled out possible injury. She was released approximately 3 hours following her arrival to the local hospital.

Figure 16. Left side, fourth row, seat configuration.

All the children on board the school bus were properly restrained by the lap belt systems and the booster seat. The restraint systems prevented the children from displacement from their respective seated positions and contact with interior components. Based on the direction of force and the rapid rotation of the school bus, the children would have been displaced laterally to the right against the high back seats and side surface of the bus if they were unrestrained. One child on board the bus noted to his father on the evening of the crash, that the bus hit a big bump, therefore the belt systems were successful in retraining the child passengers, thus preventing them from probable significant injury.

Several blood stains were noted to the left fourth seated area. A transfer was documented to the left side wall of the bus with two additional transfers noted to the forward seat back fabric. A tissue-like transfer was noted to the seat back, forward of the above injured child's position. The transfer was not consistent with the facial laceration.