CRASH DATA RESEARCH CENTER

Calspan Corporation
Buffalo, NY 14225

CALSPAN ON-SITE SCHOOL BUS CRASH INVESTIGATION

CASE NO: CA05-012

VEHICLE: 1996 INTERNATIONAL CHASSIS BLUE BIRD SCHOOL BUS

LOCATION: VIRGINIA

CRASH DATE: FEBRUARY 2005

Contract No. DTNH22-01-C-17002

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

1. Report No. CA05-012	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle Calspan On-Site School Bus Crash Investigation Vehicle: 1996 International Chassis Blue Bird School Bus Location: State of Virginia		*5. Report Date*: March 2007 *6. Performing Organization Code*	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Crash Data Research Center Calspan Corporation P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* C00410.0000.0270 *11. Contract or Grant No.* DTNH22-01-C-17002	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: February 2005 *14. Sponsoring Agency Code*	
15. Supplementary Note This on-site investigation focused on the severity of the crash and the injury sources that contributed to the death of a 16-year old male school bus passenger.			
16. Abstract This on-site investigation focused on the severity of the crash and the injury sources that contributed to the death of a 16-year old male school bus passenger. The school bus was a 1996 International Model 3800 conventional chassis with a 64-passenger Blue Bird body. The driver of the bus relinquished control as she attempted to negotiate a right curve of a two-lane roadway in a 56 km/h (35 mph) speed zone. The bus departed the right road edge and entered a drainage ditch that paralleled the roadway. The depth of the ditch caused the bus to cant to its right as it impacted a large diameter tree with the upper right A-pillar, windshield header, and roof area. The unrestrained 16-year old male passenger was seated in the first row, left side, positioned with his feet in the center isle. At impact, he was displaced forward, moving outside of the compartmentalized seating of the bus. He impacted the overhead interior mounted rear-view mirror (over the driver's position) and the edge of the intruding windshield header/bulkhead area. He sustained a massive closed head injury that involved a basilar skull fracture with brain injuries and came to rest on the forward floor of the bus, in a slumped position facing rearward. He was transported by helicopter to a regional trauma center where he expired within 11 hours of the crash. The 34-year old female bus driver was reportedly restrained by the manual 3-point lap and shoulder belt system and was not injured. There were seventeen additional student passengers onboard the bus. Seven of the seventeen students were reported as injured with one of those students sustaining a severe facial/scalp laceration. She was transported to the trauma center where she was admitted for treatment. The remaining five injured students were treated at area hospitals for minor injuries and released.			
17. Key Words School bus crash Child passenger fatality		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 19	*22. Price*

TABLE OF CONTENTS

CALSPAN ON-SITE FATAL SCHOOL BUS CRASH INVESTIGATION
CASE NO.: CA05-012
SCHOOL BUS: CHASSIS – 1996 INTERNATIONAL CHASSIS
BODY – BLUE BIRD 64 PASSENGER
LOCATION: VIRGINIA
CRASH DATE: FEBRUARY 2005

BACKGROUND

Figure 1. Exterior damage to the school bus.

This on-site investigation focused on the severity of the crash and the injury sources that contributed to the death of a 16-year old male school bus passenger. The school bus was a 1996 International Model 3800 conventional chassis with a 64-passenger Blue Bird body. The driver of the bus relinquished control as she attempted to negotiate a right curve of a two-lane roadway in a 56 km/h (35 mph) speed zone. The bus departed the right road edge and entered a drainage ditch that paralleled the roadway. The depth of the ditch caused the bus to cant to its right as it impacted a large diameter tree with the upper right A-pillar, windshield header, and roof area **(Figure 1)**. The unrestrained 16-year old male passenger was seated in the first row, left side, positioned with his feet in the center isle. At impact, he was displaced forward, moving outside of the compartmentalized seating of the bus. He impacted the overhead interior mounted rear-view mirror (over the driver's position) and the edge of the intruding windshield header/bulkhead area. He sustained a massive closed head injury that involved a basilar skull fracture with brain injuries and came to rest on the forward floor of the bus, in a slumped position facing rearward. He was transported by helicopter to a regional trauma center where he expired within 11 hours of the crash. The 34-year old female bus driver was reportedly restrained by the manual 3-point lap and shoulder belt system and was not injured. There were seventeen additional student passengers onboard the bus. Seven of the seventeen students were reported as injured with one of those students sustaining a severe facial/scalp laceration. She was transported to the trauma center where she was admitted for treatment. The remaining five injured students were treated at area hospitals for minor injuries and released.

The crash was identified by NHTSA and assigned to the Calspan Special Crash Investigations (SCI) team on February 10, 2005 as an on-site investigative effort. Cooperation was established with the investigating officer and the on-site investigation that included inspections of the bus and the crash site, was initiated on Wednesday, February 16. The bus driver was not available for an interview citing duress and legal issues.

SUMMARY

Crash Site

The crash occurred on a rural two-lane east/westbound state route during daylight hours. At the time of the crash, the weather conditions were reported as clear and dry. The asphalt travel lanes were 3 m (10.5') in width and were delineated by double yellow centerlines with no edge lines. Both road edges consisted of earth shoulders that transitioned to shallow drainage ditches. The drainage ditch adjacent to the north road edge averaged 0.6 m (2') in width and varied from 30-76 cm (12-30") in depth and was located 0.5-0.7 m (20-28") outboard of the north pavement edge. A culvert pipe crossed under the road and intersected the north ditch 13 m (42') east of the primary tree impact location. At the location of the culvert, the ditch was approximately 76 cm (30") in depth. **Figure 2** is an overall view of the crash site in the westbound direction.

Figure 2. Overall view of the crash site.

A tree line was located at the backside of the ditch bank, beginning 13 m (42') west of the referenced culvert pipe. The single line of trees consisted of three deciduous trees followed by a line of conifers (cedar). The bus impacted the trunks of the first three trees and contacted the branches of four additional trees as it re-entered the roadway prior to coming to rest. The first struck tree was 51 cm (20") in diameter with 11 and 9 cm (4.5" and 3.5") diameter trees located to the west. The single row of cedar trees continued in a westerly direction along the backside of the ditch bank. The posted speed limit in the vicinity of the crash site was 56 km/h (35 mph). The Crash Schematic is included as **Figure 20** of this report.

Vehicle Data

Chassis

The involved school bus was owned and operated by a rural county school district. The bus was built on a 1996 International 3800 conventional chassis **(Figure 3)** with a 645 cm (254") wheelbase. The chassis was identified by Vehicle Identification Number 1HVBBABP1TH (production number deleted). At the time of the SCI inspection, the odometer read 215,482.4 km (133,898.2 miles). The chassis was manufactured on May 13, 1996 and was configured with a 7.3 liter, V-8 turbo diesel engine that was linked to a 5-speed Spicer manual transmission with a floor mounted shifter. The service brakes were hydraulic 4-wheel disc with electric boost and 2-piston calipers. The Gross Vehicle Weight Rating was placarded as 12,474 kg (27,500 lb) with a front axle rating of 4,536 kg (10,000 lb) and a rear axle rating of 7,938 kg (17,500 lb). The

Figure 3. Engine compartment of the conventional chassis bus.

manufacturer recommended tire specifications were 9.00-20F on 51x18 cm (20x7") wheels with a 432 kPa (95.0 PSI) rating for the steer axle and 586 kPa (85.0 PSI) for the dual wheel rear drive axle. None of the tires or OEM steel wheels were damaged during the crash. The following table identifies the specific tire that was recorded at the time of the SCI inspection.

Table 1. Tire Data

Position	Tire Size	Tire Model/ Manufacturer	Tread Depth	Tire Pressure
LF	10R x 22.5	Michelin XZE	14 mm (17/32")	655 kPa (95.5 PSI)
RF	10R x 22.5	Michelin XZE	10 mm (12/32")	672 kPa (98 PSI)
LR Outer	10R x 22.5	Goodyear G159	12 mm (15/32")	696 kPa (101.5 PSI)
LR Inner	10R x 22.5	Michelin	13 mm (16/32")	665 kPa (97 PSI)
RR Outer	10R x 22.5	Goodyear G186	6 mm (7/32")	703 kPa (102.5 PSI)
RR Inner	10R x 22.5	Goodyear G186	4.0 mm (5/32")	713 kPa (104 PSI)

School Bus Body

The school bus body was a Blue Bird 64 passenger **(Figure 4)**. The unit was manufactured in Lafayette, Georgia on 6/96 and was identified by Body No. L021511 and a Body Service No. of L00 21690. The body was constructed of aluminum side and roof panels that were riveted and screwed to a continuous formed wall/roof bow. The bus was configured with a manually operated, two-panel right side door that closed to the mid point and a rear emergency door that was hinged at the right side. A single roof emergency exit was centered in the roof between the G- and H-pillars. The 58 cm (22.75") square hatch-type exit was removed from the vehicle at the time of the inspection. Two window emergency exits were located at the G- and H-pillar locations. Both window exits were closed pre-crash and were closed the time of the inspection.

Figure 4. Left side view of the Blue Bird bus body.

The interior was configured with the driver's compartment and a passenger area that was comprised of eleven rows of seats with a center isle **(Figure 5)**. The driver's compartment consisted of a pedestal mount low-back seat with vertical and fore and aft seat adjustments. A continuous loop three-point lap and shoulder belt system provided the manual restraint for the driver. The belt system consisted of a sliding latch plate and a retractor that was mounted to the left roof side rail. The retractor was in a locked position with the webbing fully retracted at the time of the inspection. The buckle of the safety belt system was mounted on a two-piece

Figure 5. View of an exemplar school bus looking forward in the passenger compartment.

rigid stalk that measured 35 cm (13.75”) in length and fastened to the floor with a single 10 mm (3/8”) diameter Grade 8 bolt. The driver’s webbing and latch plate yielded historical use that was consistent with the age and mileage of the vehicle.

The driver’s seat track was adjusted 9 cm (3.5”) forward of the full rear position and 6 cm (2.5”) aft of the full forward position. The vertical seat adjustment was set with the leading edge of the cushion positioned 43 cm (17”) above the floor. The steering column was fixed at an angle of 45 degrees with a horizontal distance of 60 cm (23.5”) separating the center hub of the steering wheel rim from the seat back.

Located forward and to the left of the driver’s compartment was a console that contained the wiper and heat control switches. Both wiper switches were in the off-positions. The heat controls for the pump were engaged and the heat was set at position-1 with the air vent switched to FRESH. The foot pedals consisted of symmetrical clutch and brake pedals that were separated by a distance of 6 cm (2.5”). The accelerator pedal was positioned right of the brake pedal and angled with a minimum lateral offset of 4 cm (1.5”) from the brake pedal.

The right door was manually operated by a center-mounted handle and related linkage to the two-panel, outward opening doors. Located right of the center aisle and driver’s position were the stairs that led to the door opening. The staircase consisted of three risers that transitioned the steps to the floor of the bus.

The bulkhead area that transitioned the windshield header to the roof served as a mounting point for several pieces of equipment onboard the bus. A large interior rear view mirror that measured 76 x 15 cm (30 x 6”) provided the driver with a view of the passenger compartment of the bus. This mirror was mounted on two pivot mounts attached to the face of the bulkhead. Located at the mid point of the bulkhead was a Bus-Watch audio/video monitoring system. The system consisted of two square camera boxes mounted to the centerline of the bulkhead. The lower unit measured 16 cm (6.125”) square while the upper unit measured 8 cm (3.2”) square. A label was affixed to the bulkhead that read the following:

Warning: Your Activity On This Bus May Be Under Surveillance
Bus-Watch Audio/Visual Security System
REI
Radio Engineering Industries, Inc.
Omaha, Nebraska

This school district allowed the drivers of the school bus to control and regulate the use of the Bus-Watch system. At the time of this crash, the system was not equipped with a videotape cassette; therefore there was no recording of the crash events.

A videocassette recorder (VCR) was located onboard the bus, mounted in a fabricated metal box that was secured to the floor, under the right instrument panel at the top of the staircase. The front mounted door for this VCR box was locked. The investigating

officer reported that there was no tape in the unit at the time of the crash. A plastic waste paper basket was fastened to the top of this tape box.

The passenger compartment of the bus was configured with eleven rows of seats with a center aisle. The seat backs were 60 cm (24”) in height, measured from the seat bight. The three passenger seat cushions were 97 cm (38”) in width. The horizontal spacing between the seat backs was 64 cm (25”). A padded barrier was positioned forward of the first rows and was constructed similar to a seat back rest. The seat cushion for the right seat in row 1 was 74 cm (29”) in with, configured as a two-passenger seat. The left rear seat was a two-passenger seat, which allowed for additional space for the rear emergency door. The center isle was approximately 33 cm (13”) in width, measured from the inboard edges of the seat cushions.

Crash Sequence

Pre-Crash

The driver of the school bus was assigned to this route and was familiar with the roadway and the designated bus stops. She was traveling in a westerly direction on the rural roadway at a driver-estimated speed of 56 - 59 km/h (35 - 37 mph). Several students stated to the investigating officers that the student seated in the first row left side was conversing with the driver and fellow students seated behind him. As the driver approached the crash site, she entered the shallow right curve and allowed the school bus to drift off the right road edge **(Figure 6)**. The driver’s initial statement to the first responders indicated that a non-contact vehicle was traveling in the opposite direction and crossed the centerline resulting in the bus driver initiating an avoidance maneuver to the right. A witness following the bus did not detect a non-contact vehicle and observed brake lights from the bus as the vehicle drifted off-road. It should be noted that during the SCI inspection, a spilled (open) soft drink can and a plastic wrapped pack of crackers were found on the floor with the contents sprayed onto the lower center instrument panel and floor areas.

Figure 6. Point of initial road departure of the school bus.

Figure 7. Culvert pipe and deepest point of the ditch.

The right roadside departure of the bus was evidenced by subtle rotating tire marks on the earth surface between the pavement edge and the ditch. The right side tires entered the ditch and scrubbed the backside of the ditch as the bus continued in a westerly direction.

As the ditch transitioned to a depth of 76 cm (30"') for a culvert that crossed the road **(Figure 7)**, the bus rolled laterally to the right as it continued forward. The estimated lateral right roll was approximately 45 degrees. The outboard aspect of the right front tire and wheel, along with the lower right side of the bus were spattered with mud as the bus traveled in the ditch.

Crash

The front right corner area of the engine cowl impacted the ditch bank, which fractured the leading edge of the fiberglass cowl above the headlight and turn signal assembly. Immediately rearward of this contact point, a 25 cm (10") area of the cowl fractured and separated at the wheel opening. A splash panel that was attached to the fixed cowl area of the chassis, aft of the hinge point, was also fractured and separated.

As the bus remained in a semi-rolled attitude of approximately 45 degrees, it continued forward in a westerly direction and struck a 51 cm (20") diameter deciduous (sweet gum) tree **(Figure 8)**. The initial impact involved the upper right corner of the right A-pillar and the windshield header/bulkhead area **(Figure 9)**. The impact deflected this corner area rearward 105 cm (41.25"). The upper right A-pillar was crushed rearward to the position of the right B-pillar. The diagonal attitude of the bus resulted in engagement of the roof against the tree. The tree contact extended 109 cm (43") laterally from the right corner of the A-pillar/header juncture to the centerline of the vehicle. The damage continued rearward along the roof, terminating at the right H-pillar location. The tree was debarked over an area that extended 213 cm (84") above the ground.

Figure 8. Struck tree.

Figure 9. Impact area to the windshield header/A-pillar/bulkhead juncture.

As the bus continued forward, the roof contacted a small diameter tree that was adjacent to the large diameter tree. The roof continued to swipe the branches of two additional hardwood trees and three cedar trees as it translated back to a horizontal attitude and exited the ditch. The bus came to a controlled stop on the roadway 30 m (98.4') west of the initial tree impact.

Post-Crash

The bus came to rest in the westbound travel lane, facing in a westerly direction. A male student onboard the bus moved to the rear of the vehicle and opened the rear emergency

door. He returned toward the front of the bus to check on the condition of the injured students. The bus driver was reported to have remained in her seat immediately following the crash. Another student, who later succumbed to his injuries, came to rest on the floor in a slumped attitude with his head in the area of the emergency brake lever and the videotape cassette storage box. He was lying in a face-up attitude with his feet extended toward the rear of the bus. The driver and all student passengers were removed from the bus through the rear emergency door.

The 16-year old male student passenger was removed through the rear emergency door by rescue personnel and transported by helicopter to a regional trauma center where he was diagnosed with brain death. He was mechanically supported and expired approximately 11 hours following the crash. His organs were harvested for organ donation.

Vehicle Damage

Exterior

The school bus sustained minor severity damage as a result of contact to the backside of the ditch. The fiberglass engine cowl was fractured above the right headlight and the cowling was fractured with separation at the forward aspect of the right wheel opening. Additionally, the spray shield that was mounted to the bus body aft of the wheel opening was fractured and separated from the bus. The damage to these fiberglass components was not structural.

The juncture of the right upper A-pillar, windshield header, and overhead bulkhead area **(Figure 10)** impacted the large diameter tree as the bus rolled to a near 45-degree attitude to the right. As this structural area of the bus was crushed rearward, the roof engaged the tree as the bus continued in a westerly direction. The lateral extent of direct contact damage began at the right corner of the roof/A-pillar juncture and extended 109 cm (43”) to the midline of the bus body along the top surface of the bulkhead (vertical face between the windshield header and the roof line). The maximum crush at the leading edge of the bulkhead was measured at 104 cm (41.25”) at the right corner **(Figure 11)**. The impact displaced the full width of the bulkhead/header area resulting in a combined induced and direct damage length of 203 cm (80”). A reference line was established to the original position of the bulkhead and a crush profile was documented at six equidistant points. The crush values were as follows: C1 = 11 cm (4.5”), C2 = 26 cm (10.125”), C3 = 41 cm (16.125”), C4 = 62 cm (24.25”), C5 = 79 cm (31.0”), C6 = 105 cm (41.25”).

Figure 10. Primary impact damage to the header/A-pillar area.

Figure 11. Extent of crush at the header area.

The direct contact damage extended longitudinally along the right roof side rail/upper pillar, and roof areas. The direct contact damage consisted of tree bark transfers and extended 428 cm (168.4") from the deformed location of the right upper A-pillar to the location of the right H-pillar. A vertical crush profile was documented along the right roof side rail at each pillar location. The vertical crush values at the right pillar locations were as follows: A-= 15 cm (15.25"), B-= 56 cm (22.0"), C-= 24 cm (9.5"), D-= 16 cm (6.5"), E-= 13 cm (5"), F-= 5 cm (2"), G-= 1 cm (0.5"), H-= 0 cm.

The side aspect of the right roof panels aft of the H-pillar had subtle damage that was attributed to contact with the tree branches as the bus began to upright itself and regain the travel lane. This damage consisted of a horizontal crease with transfers and measured 379 cm (149") in length and extended from the right H-to the M-pillar.

Interior

The interior of the school bus sustained severe damage that was attributed to the primary impact with the large diameter tree **(Figure 12)**. There was minor interior damage attributed to occupant contact. The driver was reportedly restrained and did not contact interior components forward of her seated position. The driver's belt system did not yield evidence of crash related loading. A fluid spatter was noted to the center and right instrument panel and below that was attributed to a spilled soft drink can that was found on the floor of the bus during the on-site SCI investigation.

Figure 12. Intrusion/interior damage to the school bus.

Figure 13. Student passenger head contact points to the mirror and header/bulkhead area.

The student passenger who was seated on the left side of the bus in row one initiated a forward trajectory from his initial right side facing position. His head impacted the large interior rear view mirror **(Figure 13)** that was fastened to the overhead bulkhead above the driver's position. The head contact was located at the right edge of the mirror glass. A skin/hair-like oil transfer was noted to the right aspect of the mirror. This contact fractured the mirror glass and deflected the right aspect of the mirror housing 11 cm (4.5") forward. The lateral deflection of the mirror unit extended 20 cm (8") inboard of the right corner.

Adjacent to the right edge of the fractured and deformed mirror were two areas of deformation (dents) at the lower edge of the overhead bulkhead/windshield header **(Figure 13)**. The first dent was circular in nature and was located 9-13 cm (3.5-5.5") right of the centerline and 1-5 cm (0.5-2") above the bottom edge of the header/bulkhead. The dent was approximately 3 mm (1/8") in depth. There was no visible body evidence (hair, tissue, fluid) associated with this dent. The second dent was located 20-28 cm (8-11") right of the vehicle's centerline and 1-6 cm (0.25-2.5") above the bottom edge. This dent was approximately 3 mm (1/8") in depth and appeared to have a vertical crease at the midline that may have resulted from induced buckling as the bulkhead was crushed rearward. The location of these dents was 117 cm (46") forward of the left first row seat back (inclusive of intrusion).

The deceased passenger came to rest on the floor in a slumped position, predominately on his back with his head in the vicinity of the emergency brake lever and the cassette tape box. He bled profusely from the ears and nose onto the cassette tape box and the floor. The investigating officer noted a single hair on the stalk of the emergency brake lever. The brake lever was hinged at the mid point and a rubber boot concealed the lower aspect of the lever/bracket. The mounting bracket for the lever within the boot appeared to be deformed to the right; however, the upper end of the lever remained in a near vertical position. There was no contact evidence on the boot or brake lever. Inspection of an exemplar bus revealed that the bottom brake lever bracket was vertical. This component was initially suspected as an injury source of the deceased passenger and remains as the investigating officer's primary injury source. A plastic release lever was incorporated into the aft portion of the upper brake lever. This protruding component was not damaged. **Figure 14** is a view of the final rest position of the deceased student passenger.

Figure 14. Final rest area of the student passenger.

It should be noted that there was no further occupant contact evidence forward of the intruding header/bulkhead area. The horizontal linkage bar for the right side door was not damaged and there was no contact evidence on the door handle hardware.

The second child passenger who sustained a serious facial injury (laceration) was seated on the left side in the eighth row. She came to rest on the right side of the bus on the seat cushion in row nine. There was no contact evidence within this trajectory; however, blood stains evidenced her final rest position. Her source of injury was not confirmed by contact evidence. A side panel that concealed the right B- through G-pillars between the top of the window units and the roof panels was crushed and separated from its sheet metal screw fasteners. This panel could have contacted the child in the left eighth row, producing her facial injury. Additional sources for the injury could have involved flying right window glazing and/or window frames.

The interior of the bus sustained severe intrusion of the right roof and pillars. The severity of the roof intrusion extended into the left row of seats. The intrusion not only reduced the passenger space at the documented seated positions, but also resulted in numerous separated components and sharp edges. Due to the scattered seating of the passengers, these edges were not a significant source of occupant injury. The maximum intrusion was located at the right first and second rows of seats and involved rearward and vertical displacement of the roof structure. The intrusions of the bus body are documented in the following table:

Table 2 – Interior Intrusions

Occupant Position	Intruded Component	Direction	Magnitude
Driver	Overhead bulkhead/header	Longitudinal	25 cm (10”)
Driver	Overhead bulkhead/header	Vertical	15 cm (6”)
Left, Row 1	Ceiling panel	Vertical	17 cm (6.5”)
Left, Row 2	Ceiling panel	Vertical	15 cm (5.75”)
Left, Row 3	Ceiling panel	Vertical	11 cm (4.5”)
Left, Row 4	Ceiling panel	Vertical	10 cm (3.75”)
Left, Row 5	Ceiling panel	Vertical	1 cm (0.5”)
Left, Row 6	Ceiling panel	Vertical	2.5 cm (1”)
Left, Row 7	Ceiling panel	Vertical	1 cm (0.25”)
Right, Row 1	Right door header	Vertical	55 cm (22.75”)
Right, Row 1	Right roof side rail	Lateral	48 cm (19”)
Right, Row 1	Right B-pillar	Lateral	28 cm (11”)
Right, Row 1	Ceiling panel	Vertical	99 cm (39”)
Right, Row 2	Ceiling panel	Vertical	52 cm (20.5”)
Right, Row 2	Roof bow	Lateral	8 cm (3”)
Right, Row 3	Ceiling panel	Vertical	38 cm (15”)
Right, Row 3	D-pillar	Longitudinal	18 cm (7”)
Right, Row 3	D-pillar	Lateral	19 cm (7.5”)
Right, Row 3	Roof bow	Lateral	17 cm (6.5”)
Right, Row 3	E-pillar	Lateral	17 cm (6.5”)
Right, Row 4	Roof side rail	Vertical	36 cm (14”)
Right, Row 4	Ceiling panel	Vertical	25 cm (10”)
Right, Row 4	E-pillar	Lateral	25 cm (10”)
Right, Row 4	F-pillar	Lateral	20 cm (8”)
Right, Row 5	Ceiling panel	Vertical	24 cm (9.5”)
Right, Row 5	G-pillar	Lateral	24 cm (9.25”)
Right, Row 6	Emergency window frame	Lateral	22 cm (8.5”)
Right, Row 6	Side rail interior trim panel	Lateral	32 cm (12.75”)

Glazing Damage

The school bus body was equipped with a two-piece gasket mounted laminated windshield with two gasket mounted quarter windows that wrapped to the A-pillars. The left glazing panel forward of the driver’s position was cracked by the rearward

displacement of the header/bulkhead area; however, it remained in place. The right windshield-glazing panel and the quarter window were cracked and separated from the gasket mount. This separation occurred as the bus engaged the large diameter tree.

The right side door was equipped with four tempered glazing panels. Both panels of the leading door and the upper panel of the aft door were shattered by the deformation from the tree impact. The lower glazing panel in the aft mounted door remained intact. All door glass was gasket mounted.

The left side glazing of the school bus consisted of laminated glass, which remained intact and undamaged. The driver's left side window was a sliding unit. This unit was mounted between the left A-and B-pillars and was tensioned without fractures due to the rearward deformation of the header/bulkhead area. The passenger windows were single hung units with operable upper panels. These panels raised and lowered to set positions within the aluminum track system. All left side windows were closed at the time of the crash. The emergency window exit was located between the G- and H-pillars. This unit was not utilized post-crash.

Numerous right side glazing panels were damaged and separated from the window frames as a result of the roof engagement against the tree. The laminated glazing panels for right seats 1-5 (pillars B- through G-) were completely separated from the body. The emergency exit panels at seat 6 were cracked, but remained within the frame. The remaining glazing panels for seats 7-11 remained intact and undamaged.

The back wall of the bus contained two fixed gasket mounted glazing panels that measured 51 cm (20.125") square. Both laminated panels remained intact. The rear emergency door was equipped with glass panels that remained intact. This emergency exit was utilized to remove all occupants of the bus post-crash.

Exterior Pillar Damage

The body of the school bus was built with a pillar system that consisted of fabricated A- and B-pillars and one-piece stamped pillar/roof bows that extended from floor-to-floor, forming the side and roof structures of the bus from the C- to the M-pillars. The left upper A-pillar was deflected rearward and rotated slightly in a clockwise direction as a result of the header/bulkhead engagement against the large diameter tree. The remaining left side pillars were not damaged.

The right side pillars sustained severe damage from the tree engagement **(Figure 15)**. The right upper A-pillar at the windshield header was crushed rearward approximately 91 cm (36") beyond the original location of the B-pillar. The pillar deflection fractured two welds and four sheet metal screws below the beltline which resulted in a separation of the mid A-pillar from the front wall of the bus body. The impact also crushed the upper aspect of the right

Figure 15. Right side pillar collapse.

side doors beyond the right B-pillar location.

The right B-pillar was crushed rearward to a near horizontal position. The measured angle of the pillar was 85 degrees aft of vertical. The upper aspect of the pillar remained secure to the roof side rail. The top of the right C-pillar was deflected rearward and was completely torn from the side rail. The measured angle of this pillar was 75 degrees aft of its original vertical position. The right D-pillar was crushed rearward and was partially separated at the level of the beltline. The measured angle of this pillar was 55 degrees aft of vertical. The right E- and F-pillars were deflected to angles of 30 degrees with the damage ending at the longitudinal position of the right H-pillar. The G-pillar was displaced to an angle of 18 degrees with 2 degrees of displacement of the upper aspect of the H-pillar.

Roof Panel Separation

Exterior

The exterior roof system was comprised of eight aluminum panels that extended laterally from side rail-to-side rail and were fastened to the body with a series of rivets to the side rails and roof bows. Three areas of panel separation resulted from the tree engagement **(Figure 16)**. The first panel was 91 cm (36") in width and extended from the windshield header to the B-pillars. This panel overlapped the leading edge of the second panel that was 142 cm (55.75") in width and extended from the B- to the D-pillars. At the location of the right C-pillar, the roof panel was torn in a triangular pattern that measured 10 cm (4") longitudinally and 53 cm (21") laterally, originating at the right side rail. This tear resulted in the separation of seven rivets.

Figure 16. Exterior roof panel separation.

The third roof panel was 142 cm (56") in width and extended from the D-pillars to the F-pillars. At the location of the right D-pillar, there was extensive roof panel separation of the second and third panels at the overlap seam. A triangular separation measured 46 cm (18") longitudinally at the side rail and approximately 46 cm (18") laterally at the aft edge of the second panel and 61 cm (24") laterally at the leading edge of the third panel, both originating at the side rail, extending inboard toward the midline of the roof.

The fourth roof panel was 142 cm (56") in width and extended from the F- to the H-pillar. This panel was deformed rearward from engagement against the large diameter tree; however, it remained intact.

The fifth through eighth roof panels sustained minor sideswipe-type damage from contact with the tree branches as the bus began to regain the travel lane. There was no longitudinal displacement or buckling of these panels.

Interior Body Panel Separation

The interior roof panels extended laterally across the interior and were secured to the roof bows with sheet metal screws. Although the panels were deformed by the roof deformation, none of the laterally oriented panels separated. Longitudinally oriented sheet metal panels were mounted to the vertical surface of the bus between the side window frames and the interior roof panels. The forward panel on the right that extended from the B- to the G-pillar was 30 cm (11") in height and 354 cm (139.5") in length and was secured to each pillar with four sheet metal screws. Due to the roof and side rail deformation, this panel crushed and completely separated from the roof bows/pillars. At the time of the SCI inspection, this panel was found lying across the right row of seats.

All right side window frames and the associated glazing from the right B- through G-pillars separated. These units were located in the first five rows of the bus. Two sheet metal screws and aluminum washers were used to secure the aluminum window frames to each pillar.

Manual Safety Belt Systems

The school bus was equipped with manual safety belts for the driver's position and the first row of the passenger compartment. The driver's safety belt system consisted of a 3-point continuous loop lap and shoulder belt with a sliding latch plate that retracted onto a left side rail mounted retractor located between the left B- and C-pillars. The retractor was jammed with the belt in the stowed position; therefore, the specific type of retractor was unknown. The belt system buckled to a stalk mounted buckle that was secured to the floor of the bus at the inboard aspect of the driver's seat. The rigid stalk was 35 cm (13.75") in length and consisted of two lengths of steel that were bolted at the mid point with a Grade 5, 10 mm (3/8") diameter bolt. The belt system displayed routine historical wear marks on the latch plate with subtle wear at the edges of the webbing. There was no loading evidence to the belt system. The driver was allegedly restrained by the belt system at the time of the crash. There were no occupant contacts within her position and she reportedly remained in her position during and after the crash. The retractor probably jammed due to debris from the crash following the driver's release of the belt system.

The left first row three-passenger seat was equipped with a single fixed length adjustable lap belt. This belt system was equipped with a cinching latch plate. The webbing for this belt system was tied to the seat frame with a simple knot under the seat cushion. The webbing was fed through the seat bight and rested on the seat cushion. This belt system was installed for use by pre-school aged children who were occasionally transported on this bus. The single belt was large enough to restrain three children in this seat position. The passenger did not use this belt at the time of the crash.

The right first row seat was a two-passenger seat that was configured with a similar belt system as the left side. The belt webbing was tied with a knot to the square-stock seat frame. This belt webbing was not exposed to the top surface of the seat cushion. At the time if the SCI inspection, the webbing was hanging from the seat frame with the latch plate and buckle ends resting on the bus floor.

None of the remaining ten rows of seats within the bus compartment were equipped with safety belt systems.

Occupant Demographics

Driver

Age/Sex:	34-year old/Female
Height:	Not available
Weight:	Estimated at 59 kg (130 lb)
Manual Belt Usage:	3-point lap and shoulder belt system
Usage Source:	Preliminary police investigation, no loading evidence to support usage
Eyewear:	Not available
Bus Driving Experience:	5 years

Driver Injuries

Injury	Injury Severity (AIS 90/ Update 98)	Injury Source
Not reported as injured	N/A	N/A

**Source - Police*

Driver Kinematics

The driver of the school bus was seated in a mid track position and allegedly restrained by the manual 3-point lap and shoulder belt system. Although the belt system yielded historical wear marks that were consistent with the vehicle age and mileage, the belt webbing and hardware did not yield loading evidence from the crash. Additionally, the belt webbing would not extend from the retractor at the time of this SCI investigation; therefore belt usage could not be confirmed by vehicle inspection. There were no distinct occupant contact points in the vicinity of the driver's position and the driver was reported as not injured. This further supported the use of the manual belt system.

As the vehicle entered the ditch and rolled laterally to the right, the driver was probably displaced from her driving position slightly to her right. At impact with the trees, the driver's trajectory would have been translated to a forward and right direction with respect to the rolled attitude of the bus. There were no contact points to the frontal components forward of the driver's position. If the safety belt system was worn, the belt restrained the driver into position and prevented her from possible injury. The investigating officer reported that the driver was not injured during the crash; however, she did seek medical attention for emotional distress.

Fatal Passenger

Age/Sex:	16-year old/Male
Seated Position:	Row 1, left side
Seating Posture:	Reportedly, this passenger was seated facing the aisle with his feet positioned in the center aisle
Height:	193 cm (76”), estimated by medical examiner
Weight:	104 kg (230 lb), estimated by medical examiner
Manual Restraint Usage:	None, although a single lap belt was available for this seat position
Usage Source:	Passenger kinematics, final rest position
Eyewear:	None

Fatal Passenger Injuries

Injury	*Injury Severity (AIS 90/Update 98)*	*Possible Injury Source*
Bilateral minimal uncal (brainstem) herniation	Critical (140202.5,8)	Windshield header/bulkhead
Significant intra cerebral hemorrhage, NFS	Severe (140638.4,9)	Windshield header/bulkhead
Basilar skull fracture to posterior splenoid and left mastoid	Serious (150200.3,8)	Windshield header/bulkhead
Subarachnoid hemorrhage, NFS	Serious (140684.3,9)	Windshield header/bulkhead
Diffuse brain edema, NFS	Serious (140660.3,9)	Windshield header/bulkhead
2.5 cm (1”) laceration to the posterior left head	Minor (190602.1,6)	Windshield header/bulkhead

Source – Hospital Records

Fatal Passenger Kinematics

The 16-year old male passenger of the school bus boarded the bus several minutes prior to the crash. He was seated in the first row left side and was positioned in a side facing attitude with his feet in the center aisle while he conversed with the driver and a student passenger seated behind him. Although this seat was equipped with a manual lap belt for all three positions, this student was not restrained.

Figure 17. Trajectory and contact points of the student passenger.

As the school bus entered the ditch and rolled laterally to the right, the 16-year old male passenger moved to his right and forward outside the protection of the compartmentalized seating. As the school bus impacted the large diameter tree, the passenger’s trajectory translated to a

forward motion and slightly left due to the rolled attitude of the bus **(Figure 17)**. The tree impact crushed the overhead header/bulkhead rearward and downward intruding this component into the passenger's trajectory. He impacted the right aspect of the large interior mounted rear view mirror. An oily skin or hair transfer was noted to the right edge of the mirror glass. This contact deformed the right edge of the mirror 11 cm (4.5") forward and fractured the mirror glass **(Figure 18)**. The left side of the passenger's head probably impacted the intruding header/bulkhead adjacent to the mirror contact. Two shallow dents were noted to the vertical face directly above the bottom edge **(Figure 19)**. This contact probably resulted in the head injuries the passenger sustained. In addition to the basilar skull fracture, the 16-year old male passenger sustained a herniation of the brainstem, a subarachnoid hemorrhage, a diffuse brain edema, an intra cerebral hemorrhage, and a head laceration.

Figure 18. Head contact to the mirror .

Figure 19. Head contact to the header/bulkhead .

The passenger came to rest in a slumped position on the floor of the bus, with his head resting below the instrument panel between the emergency brake lever and the videotape storage box, facing rearward. He was bleeding profusely from the head as evidenced by pooled blood in the box that stored the emergency reflective triangles, on the videotape storage box, and the floor of the bus.

Immediately following the crash, the passenger reportedly remained in a semi-coherent state, however, his condition rapidly deteriorated. First responders to the crash site repositioned the passenger to a supine position. He was treated on the bus and placed on a backboard. The passenger was subsequently transported by helicopter to a regional trauma center where he was supported mechanically. He expired at this facility approximately 11 hours following the crash.

Additional Passengers

The school bus was occupied by 17 additional student passengers at the time of the crash. The specific seating of these children by age, gender, and position are identified in the table that follows. None of these children were seated in positions equipped with lap belts. Seven of these passengers sustained police reported minor-to-incapacitating injuries levels. Four of these passengers were transported to local hospitals for treatment

of their injuries and were released. Of the seven injured students, the 14-year old female who was seated in the left side of Row 9 sustained a large facial laceration and was transported and admitted to a regional trauma center for surgical repair of the laceration.

The table on the following page identifies the seating positions, age, gender, and injury level for the student passengers by seat row:

Table 3. Student Passenger Seating

Row 1			16-year old male Fatal			
Row 2		13-year old female Not injured	14-year old female Not injured		12-year old female A-injury, transported	
Row 3		11-year old male Not injured	14-year old male Not injured		12-year old male C-injury, not transported	
Row 4					12-year old male A-injury, transported	
Row 5		13-year old male A-injury, transported	15-year old female A-injury, transported	13-year old male A-injury, transported		14-year old male Not injured
Row 6					12-year old male Not injured	
Row 7						
Row 8		14-year old male Not injured	18-year old male Not injured			
Row 9			*14-year old female A-injury facial laceration		15-year old male Not injured	
Row 10						
Row 11					16-year old female Not injured	

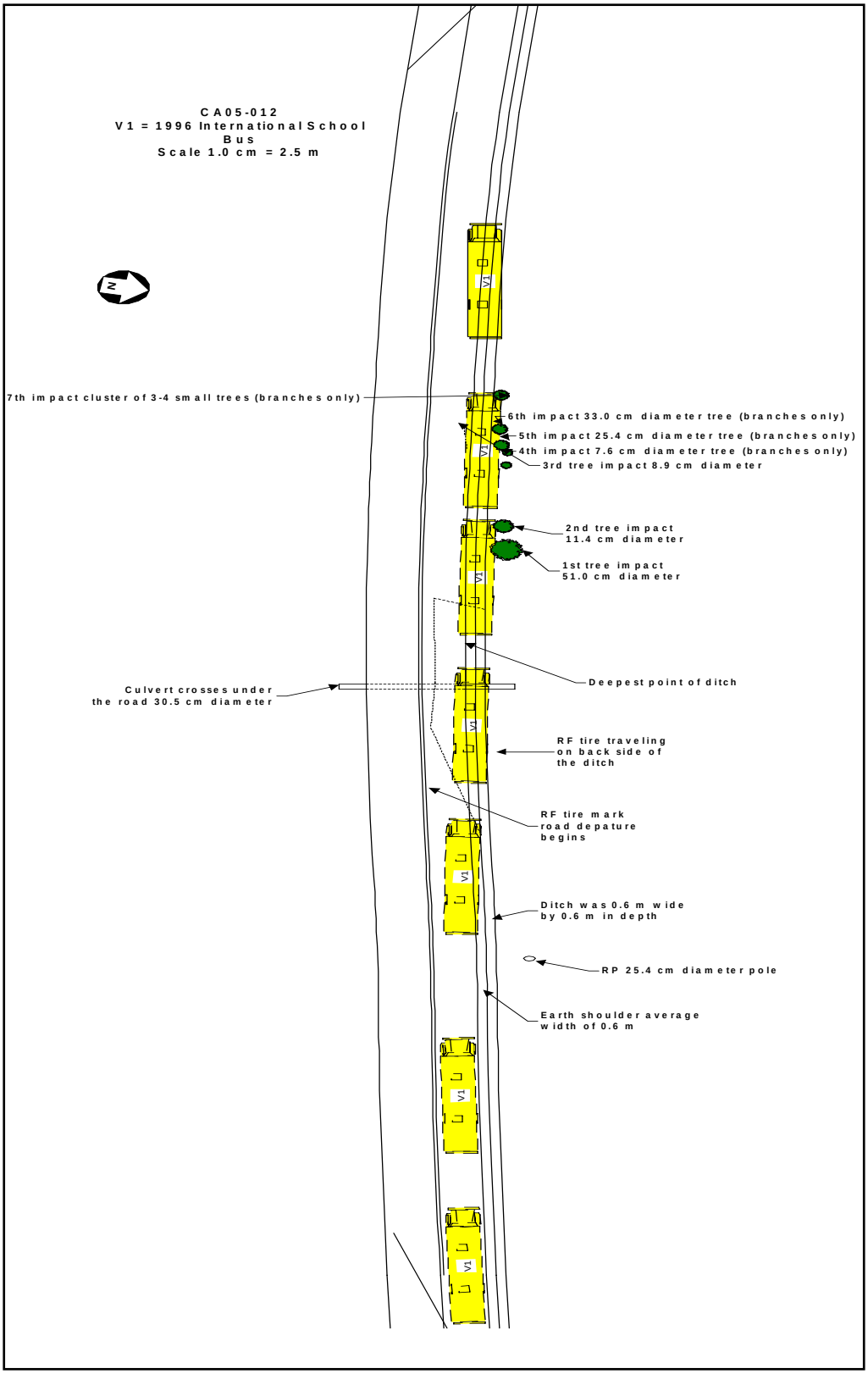

Figure 20 – SCI Crash Schematic