

**TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION**

**Veridian/Calspan
Buffalo, New York 14225**

THREE-VEHICLE SCHOOL BUS CRASH INVESTIGATION

VERIDIAN CASE NO. CA98-061

LOCATION: NEW YORK

CRASH DATE: NOVEMBER, 1998

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be 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 of the involved vehicle(s) or their safety systems.

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<p>17. <i>Abstract</i></p> <p>This on-site school bus crash investigation focused on the injury mechanisms and restraint usage of 35 students transported by two school buses that were involved in a three vehicle crash. The crash involved a 1994 International 65 passenger school bus, a 1997 Isuzu medium duty delivery truck and a 1995 Ford van-based school bus. Both school buses were equipped with safety belts for all occupants. The Ford van-based school bus was occupied by a restrained female driver, one unrestrained adult female monitor and 3 unrestrained students. The Isuzu delivery truck was occupied by two unrestrained adult males. The International based full-size bus was occupied by a restrained male driver and 32 unrestrained students. The front-to-rear multiple collision event resulted in minor injuries to 9 students and 5 adults. All the injured occupants were transported, treated and released the day of the crash.</p> <p>Events surrounding the crash were televised locally and subsequently forwarded to the Field Operations Branch of the National Highway Traffic Safety Administration (NHTSA) by the Special Crash Investigation (SCI) team at Veridian/Calspan. The FOB directed the Calspan SCI team to conduct an on-site investigation on November 5, 1998</p>			
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BACKGROUND

This on-site school bus crash investigation focused on the injury mechanisms and restraint usage of 35 students transported by two school buses that were involved in a three vehicle crash. The crash involved a 1994 International 65 passenger school bus, a 1997 Isuzu medium duty delivery truck and a 1995 Ford van-based school bus. Both school buses were equipped with safety belts for all occupants. The Ford based mini-bus was occupied by a restrained female driver, one unrestrained adult female monitor and 3 unrestrained students. The Isuzu delivery truck was occupied by two unrestrained adult males. The International based full-size bus was occupied by a restrained male driver and 32 unrestrained students. The front-to-rear multiple collision event resulted in minor injuries to 9 students and 5 adults. All the injured occupants were transported, treated and released the day of the crash.

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SUMMARY

This three vehicle front-to-rear crash occurred during the afternoon hours in November, 1998. At the time of the crash, it was daylight and the weather was not a factor. The crash took place in the westbound lane of an east/west two lane roadway located within a suburban residential district. The total width of the travel lanes measured 8.5 m (27.9 ft) and the overall width of the road was 12.0 m (39.4 ft). There was a negative 2% grade in the westbound direction. The speed limit in the area of the crash was 72 km/h (45 mph). **Figure 1** is a westbound view along the roadway at the crash scene..



Figure 1: Westbound trajectory view of the crash scene.

The crash occurred when the westbound lead school bus, a 1995 Ford van-based school bus, stopped to discharge a student at his residence. A 1997 Isuzu medium/heavy delivery truck stopped behind the Ford and was subsequently struck in the rear by a 1994 International 65 passenger school bus. The International bus had just began its afternoon route from a middle school which was located 1.1 km (0.7 miles) east of the crash scene. Reportedly, the driver of the International school bus was distracted by misbehaving students and took his eyes off the road. The driver

estimated he was traveling approximately 56 km/h (35 mph). When he returned his concentration to the roadway, he observed the stopped Isuzu truck, applied counterclockwise steer and immediately applied the brakes. The rear tires of the bus locked and the vehicle skidded approximately 1.9 m (6.2 ft) where it struck the rear of the Isuzu in a 12/6 o'clock impact configuration. The point of impact was identified by a series of gouge marks attributed to contact from the rear lift gate of the truck.

The International continued skidding westward and pushed the truck forward, approximately 10.3 m (33.8 ft), where the front of the truck struck the rear of the Ford mini-bus in a secondary 12/6 o'clock impact. This secondary impact displaced the Ford mini bus and the Isuzu forward and the vehicles came to rest in the westbound lane of the road approximately 12.8 m (42 ft) from the point of the secondary impact. After the second impact, the driver of the International school bus released the brakes and drove the bus to a controlled stop on the eastbound shoulder of the roadway. Inspection of the scene identified a total skid distance of 17.3 m (56.7 ft) of attributed to the rear tires of the International bus. **Figures 2 and 3** are westward views of the crash scene taken during the police investigation. **Figure 4** is a schematic of the crash scene.



Figure 2: Westward trajectory view of the 1994 International bus.



Figure 3: Westward view of the vehicles at final rest.

The International school bus sustained moderate frontal deformation and was towed from the scene. The body of the bus reportedly shifted forward on the frame an estimated distance of 3.8 cm (1.5 in). It was subsequently inspected by the New York State Department of Transportation for mechanical failures with none detected. The Ford van-based school bus and Isuzu truck sustained disabling damage and were also towed from the scene.

The driver of the International bus was a 42 year old male. He was restrained at the time of the crash by the vehicle's 2-point lap belt system. He reportedly sustained contusions to his upper legs and abdomen as a result of restraint loading. A total of 32 elementary school age students were on-board the bus. None of the students were restrained by the available lap belt system. Seven students were transported to a local hospital for examination. The injuries were described by the investigating police officer as "minor bumps and bruises". One child did have a bloody nose.

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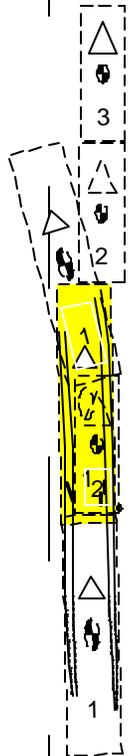
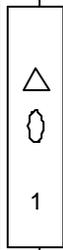
Vehicle #1 - 1994 International School Bus
Vehicle #2 - 1997 Isuzu Truck
Vehicle #3 - 1995 Ford Van-Based School Bus



Scale
1 cm = 2.5 m

Speed limit
72 km/h (45 mph)

Asphalt
0.7 coefficient of friction



Utility pole

Grass

Asphalt

Stone shoulder

Ditch 81 cm
(32") deep

-1 degree

The driver of the Ford van-based bus was a 43 year old female. She was restrained at the time of the crash and reportedly was uninjured. The bus was occupied by a 37 year old unrestrained female and three unrestrained students. The adult female was seated on the right side in row 1. She had a complaint of neck pain post-crash and was transported. Two of the students reportedly sustained minor injuries and were also transported.

The driver and right front passenger of the Isuzu truck were a 27 year old male and a 28 year old male, respectively. Both occupants were unrestrained and transported for minor head injuries resultant to contact with the truck's windshield.

VEHICLE 1 - 1994 International based full-size Bus

The 1994 International full-size school bus was identified by a Vehicle Identification Number (VIN): 1HVBBPEN5RH(production sequence deleted), **Figure 5**. The bus chassis was model 3800 4x2, with a gross vehicle weight rating (GVWR) of 12,737 kg (28,080 lb). The date of chassis manufacture was 8/93. The odometer read 86,800 km (53,937 miles) at inspection. The vehicle was equipped with a diesel powered V-8 engine, 3-speed automatic transmission and air brakes. Post-crash NYSDOT inspection of the vehicle did not reveal any defects.



Figure 5: Left front three-quarter view of the International bus.

The school bus body was manufactured by Blue Bird in January 1994. The body had a capacity for 65 children/43 adults. The following nomenclature identified the body:

Body No:	B056092
Capacity:	65
Model Year:	94
Body Service No:	251788
	045-NY-65-OOWC-BBB

The vehicle sustained 201 cm (79 in) of direct contact across the entire width of the frontal plane. The maximum crush was 50.2 cm (19.75 in) and was located 8.9 cm (3.5 in) left of vehicle centerline. The maximum crush occurred at the unsupported center section of the front bumper and was resultant to direct contact with the bed frame of the Isuzu truck. The hood fractured in the impact and was removed prior to SCI inspection. The radiator was damaged and displaced rearward due to the direct contact with the truck bed. The bus's engine and transmission shifted rearward and down and the drive shaft buckled. The right wheelbase was foreshortened 7.6 cm (3.0 in). The left wheelbase dimension was unchanged.

The school bus body was attached to the chassis frame by a series of metal clips. **Figure 6** is a view of the left frame rail and the method of attachment. The front of the bus is toward the right side of the figure.

Referring to Figure 6, tightening the fastener (attached to the bus body) increases the clamping force between the clip and frame rail. This method of attachment permits the bus body to slide relative to the frame. By virtue of this degree of freedom, a portion of the crash forces are absorbed by overcoming the friction between the bus body and the frame as the frame is decelerated in a crash and the body slides forward. In this manner, the crash forces transmitted to the occupant compartment are reduced. Inspection of the clips revealed the body slid forward approximately 3.8 cm (1.5 in) relative to the frame in this crash.



Figure 6: View of the shift of the bus body relative to the frame rail.

The front access to the bus interior was a forward opening 64.8 cm (25.5 in) accordion door. The entrance consisted of two stair treads and three risers from ground to floor level. The risers measured 34.0 cm (13.4 in), 31.2 cm (12.3 in) and 32.5 cm (12.8 in) from ground to floor respectively. The first and second stairs measured 64.8 cm by 43 cm (25.5 in by 17 in) and 52.1 cm by 28 cm (20.5 in by 11 in), width by depth, respectively.

Figure 7 is an overall view of the seating configuration. There were 11 rows of high backed seats symmetrically spaced over the interior area that measured 2.3 m by 8.1 m (7.5 ft by 26.5 ft), width by length. The individual seats measured 97.8 cm by 39.4 cm (38.5 in by 15.5 in) width by depth, and had the capacity to seat three students. The exception was the left seat of row 11 which seated two students and measured 67.3 cm by 39.4 cm (26.5 in by 15.5 in). The seat cushions were 41.9 cm (16.5 in) above the floor. The tops of the seat backs measured 74 cm (29 in) above the seat cushion, 109 cm (43 in) above the floor. The seat backs were reclined 7 to 8 degrees.



Figure 7: Overall view of the bus interior seating arrangement.

Each seat was equipped with three sets of Type 1 lap belts, except the left seat in row 11 which was equipped with two belts. The belts were color coded and configured as follows: red outboard, tan center and black inboard. **Figure 8** is a view of the typical belt condition found during the inspection. Examination of the restraints revealed that 61 of the 65 lap belts were buckled and could not have been used in the crash. Three of the belts were tucked between the side wall and the seat, not readily available. Further, 49 of the 65 belts were improperly adjusted, either the latch plate adjustment was too short or too long to provide a means of proper restraint. In his



Figure 8: View of the typical condition of the lap belts.

interview with the police, the driver indicated it was his daily practice to latch the belts together, thus making sure the seat belts were available for the students. However, this practice may have been a disservice to the passengers in that the passengers were more likely to sit on the belts rather than unbuckle, adjust and re-buckle. SCI and police investigations determined that none of the students on-board the bus were restrained in the crash. The driver indicated that the students were not restrained as well. Further it was not their practice to wear the seat belts.

VEHICLE 1 - Occupant Issues

The 1994 International full size bus was driven by a 42 year old male with a reported height and weight of 173 cm (68 in) and 136 kg (300 lb), respectively. The driver had approximately eight years of school bus driving experience and had driven for this particular school system 14 months prior to the crash. He was restrained by the vehicle's two-point lap belt. The bus was loaded with 7th and 8th grade middle school students and was in the process of its afternoon run. The bus was within 1.6 km (1.0 mile) of the school at the time of the crash.

The driver estimated the bus was traveling approximately 56 km/h (35 mph). He was distracted by misbehaving students and upon returning his concentration to the roadway, he recognized stopped traffic ahead. He attempted to avoid the crash by applying counterclockwise steer and locking the brakes. At impact, the driver responded to the 12 o'clock direction of the impact force and initiated a forward trajectory. He loaded the lap belt with his lower torso and loaded the steering column through his arms. The driver sustained several contusions about his upper thighs and abdomen from the restraint loading. He did not recall contacting any other interior component. He was transported to a local hospital as a precaution, examined and released. He was sore for several days post-crash. He was off work for two days. His employment was then terminated.

There were a total of 32 students, aged 13 to 15 years, on-board the bus, 16 male and 16 female. The students were evenly distributed throughout the bus. The driver reported that the student's seated height placed the top of their heads approximately level with the top of the seat backs. None of the students were restrained by the available lap belt system. The driver indicated the seat belts were made available, however it was the students discretion whether to wear them.

At impact, the unrestrained students responded to the 12 o'clock direction of the impact and initiated a forward trajectory. The student's probably moved forward and contacted the seat back in front with their knees and lower legs. This contact would have arrested the forward motion of the lower extremities and lower torso and modulated the forward motion of the upper torso. Dependent on the position of their arms, the students contacted the seat backs with their arms, shoulder and/or heads. The students then rebounded back into their seats. The driver indicated that all of the students were in their seats after the crash.

Seven students, six male and one female, were transported to a local hospital as a precaution. The students were examined and then released. None of the students were seriously injured. The driver reported that the injuries were comprised of "bumps and bruises". One male student did get a bloody nose from contact

with the seat back. A small blood transfer was identified on the seat back of row 7 left during the bus inspection. Seat inspection identified many small transfers and scuffs on the majority of the seat backs, however it was not possible to ascertain the age and/or source of the contacts. Many of these contacts were undoubtedly the result of normal every day use.

VEHICLE 2 - 1997 Isuzu medium duty straight truck

Figure 9 is a left front three-quarter view of the 1997 Isuzu NPR medium duty truck. The vehicle was identified by a Vehicle Identification Number (VIN): JALB4B1K5V7 (production sequence deleted). The truck was manufactured as an incomplete vehicle in October 1996 and had a gross vehicle weight rating of 4,536-6,350 kg (10,000-14,000 lb). Post manufacture modifications included a 1.3 m (4.4 ft) rearward extension of the frame rails and the addition of a 5.5 m (18 ft) box enclosure. The vehicle was equipped with a 3.9 liter, L4 diesel engine. The odometer read 52,961 miles at the time of the inspection.

The truck sustained 191.8 cm (75.5 in) of direct contact damage along the rear edge of the platform, **Figure 10**, as a result of the impact from the International full size bus (Vehicle 1). The direct damage began 72.4 cm (28.5 in) right of center and extended to the left corner. The maximum crush measured 14.0 cm (5.5 in) and was located 72.4 cm (28.5 in) left of center. The crash forces deformed the 2 dock guards located left of center and displaced the step platform attached to the end of the guards, refer to Figure 9.

The 6 o'clock direction of the impact displaced the Isuzu forward into the back plane of the van-based bus (Vehicle 3). The Isuzu's front plane sustained direct contact damage across its full 175 cm (69 in) frontal width. The measured crush profile was as follows: C1=34.3 cm (13.5 in), C2=10.7 cm (4.2 in), C3=6.4 cm (2.5 in), C4=12.7 cm (5.0 in), C5=3.0 cm (1.2 in), C6=2.3 cm (0.9 in). The damaged components included: the front bumper, grille, hood and head lamps.



Figure 9: Left front three-quarter view of the Isuzu.



Figure 10: Rear view of the Isuzu.

The Isuzu was driven by a 28 year old unrestrained male. The right front passenger was an unrestrained 27 year old male. Immediately prior to the crash, the Isuzu was stopped behind the Ford van-based bus. Both occupants were seated in a presumed normal posture. At impact, the front plane of Vehicle 1

impacted the back of the Isuzu in a 12/6 o'clock impact configuration. The 6 o'clock direction of the impact force caused both occupants to initiate a rearward trajectory, moving into and compressing their respective seat backs. The force of the impact caused the Isuzu to be displaced forward and into a secondary 12/6 o'clock collision with back plane of Vehicle 3. The 12 o'clock direction of the secondary impact caused the occupants to then rebound and initiate a forward trajectory and into contact with the windshield. Inspection of the Isuzu's windshield identified four fracture sites. Two of the fracture sites were located directly forward of the driver's position and were associated to contact from the driver's head and left hand. A fracture was located directly forward of the right front passenger and was related to contact from the right front passenger's head. The fourth fracture site was located approximately on the vehicle centerline and was attributed to contact from a loose fire extinguisher found on the vehicle floorboard. Both occupants of the Isuzu had a post-crash complaint of head pain resultant to windshield contact. They were both transported, treated and released the day of the crash.

VEHICLE 3 - 1995 Ford E350 van-based school bus

The 1995 Ford E350 van-based school bus was identified by the Vehicle Identification Number (VIN): 1FDJE37F6SH (production sequence deleted), **Figure 11**. The Ford E350 cab and chassis was manufactured as an incomplete vehicle in February 1995. The addition of a Carpenter bus body, model number 017-NY-19-00WC-EMC, completed the manufacture. The Carpenter body had a capacity of 19 children/10 adults. The body's manufacture date was January 1996. The completed bus had a gross vehicle weight rating of 9600 lb. The electronic odometer was inoperative at the time of the inspection.



Figure 11: Left side view of the 1995 Ford mini-bus.



Figure 12: Right rear three-quarter view of the damaged back plane.

The Ford sustained direct contact damage across the entire 188 cm (74 in) rearend width of the vehicle, **Figure 12**. The Collision Deformation Classification (CDC) for the impact with the Isuzu truck was 6-BDEW-3. The measured crush profile was as follows: C1=2.8 cm (1.1 in), C2=9.4 cm (3.7 in), C3=29.7 cm (11.7 in), C4=24.1 cm (9.5 in), C5=23.4 cm (9.2 in), C6=24.1 cm (9.5 in). The maximum deformation measured 30.5 cm (12.0 in) and was located 7.4 cm (2.9 in) left of the vehicle centerline. The force of the impact deformed and foreshortened the right frame rail 4.6 cm (1.8 in).

The Ford bus was equipped with 5 rows of high backed seats, **Figure 13**. The seats were symmetrically spaced over an interior area that measured 1.9 m by 3.7 m (6.3 ft by 12.0 ft), width by length. The seat cushion measured 76.2 cm by 39.4 cm (30.0 in by 15.5 in) width by depth and had the capacity to seat two students. A single seat was located on the right side of row 5 and measured 50.8 cm by 39.4 cm (20.0 in by 15.5 in). The tops of the seat backs measured 63.5 cm (25 in) above the cushion and were reclined approximately 8 degrees.



Figure 13: Interior seat configuration of the Ford mini-bus.

Each seat was equipped with two sets of Type 1 lap belts, except the right seat in row 5 which was equipped with 1 belt. The belts were color coded and configured with the outboard belt red and the inboard belt black. Inspection of the restraints indicated that none of the seat belts were in use at the time of the crash. Examination revealed that the sliding latch plates of all 19 lap belts were at the maximum adjustment. This manner of adjustment would have been inappropriate for use by students. Referring to Figure 13, some of the belts were found slung over the seat backs at inspection. The balance of the belts were tucked between the seat cushion and seat back or trapped between the cushion and side wall. The driver of the bus reported that none of the passengers were restrained.

VEHICLE 3 - Occupant Issues

The bus was driven by a 43 year old female with a reported height and weight of 173 cm (68 in) and 113 kg (250 lb).. She was restrained by the vehicle's three-point lap and shoulder belt system. Immediately prior to the crash, she had just discharged a student, closed the door and was in the process of getting under way. She did not see the approaching bus and was unaware of the impending crash. Upon impact, she responded to the 6 o'clock direction of force, initiated a rearward trajectory and loaded the seat back. She then rebounded and loaded the 3-point restraint. Her only injuries were several minor contusions to her left forearm resultant to contact with the interior panel of the driver's door. She complained of some soreness to her shoulder and chest due to the restraint loading. She was reportedly off work for two days.

An adult monitor and three students were on-board the van-based school bus at the time of the crash. The monitor was a 37 year old female with a reported height and weight of 165 cm (65 in) and 75 kg (165 lb). She was seated on the right side of the bus in the first row. She was facing forward in a normal posture. At impact, she responded to the 6 o'clock direction of force by initiating a rearward trajectory and loaded the seat back. Her head/neck was above the level of the seat back and extended rearward. She reportedly hit her head on the right side wall and/or glazing. She then rebounded without further contact. Inspection of the seat revealed approximately 6.0 cm (2.4 in) of deformation along the lower aspect of the seat back, at the juncture with the seat cushion, **Figure 14**. The deformation was located 18 cm (7.0 in) from the right side wall of the bus. This deformation occurred as a direct result of occupant loading.



Figure 14: View of the deformed seat back - Row 1 right side.

The three students on-board the bus were male 7th grade students, approximately 13 years of age. They were seated in row 2 left, row 3 left and row 3 right respectively. The students responded to the 6 o'clock direction of force by initiating a rearward trajectory and loading the seat backs. The respective seated heights of the students probably were contained within the dimension of the high backed seats. Their head/necks were supported by the seat backs during the rearward trajectory. The boys then rebounded and initiated a forward trajectory. The occupant of row 2 left was reportedly found on the floor post-crash.

The seat backs of row 2 left and row 3 left did have measurable deformation. There was 1.3 cm (0.5 in) of deformation measured at the lower edge of the seat back in row 2 left. The deformation was located 45.7 cm (18.0 in) in-board of the left side wall. The deformation of the seat back in row 3 left was located 19.1 cm (7.5 in) in-board of the left side wall and measured approximately 2.5 cm (1.0 in).

All occupants of the Ford bus were transported to a local hospital as a precaution. They were all examined, treated and released the day of the crash. The driver reported that none of the students appeared to be seriously injured.