TRANSPORTATION SCIENCES
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GENERAL DYNAMICS ON-SITE CHILD SAFETY SEAT FATALITY INVESTIGATION
SCI TECHNICAL SUMMARY REPORT

CASE NO: CA04-022

VEHICLE: 1991 CHEVROLET LUMINA APV

LOCATION: STATE OF FLORIDA

CRASH DATE: NOVEMBER 2003

Contract No. DTNH22-01-C-17002

Prepared for:

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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 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

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15. Supplementary Note On-site investigation that focused on the fatal injury mechanisms of a 3-year-old male child restrained in a forward-facing convertible Child Safety Seat (CSS) that was installed in a 1991 Chevrolet Lumina APV minivan. The Lumina was involved in a severe left side intersection crash and the 3-year-old male child sustained fatal injuries. A 7-year-old child was ejected from the vehicle during the crash.			
16. Abstract This on-site investigative effort focused on the fatal injury mechanisms of a 3-year-old male child passenger that was restrained in a forward-facing convertible child safety seat (CSS), which was positioned in a 1991 Chevrolet Lumina APV minivan. The Lumina was also occupied by an unrestrained 53-year-old female driver, a restrained 10-year-old female front right passenger, and an unrestrained 7–year-old female rear left passenger. The driver brought the Lumina to a controlled stop at a four-leg intersection, which was controlled by stop signs for east/west traffic. A 2000 Toyota Tundra pickup truck with a utility trailer in tow was traveling northbound on approach to the intersection at a police-reported speed of 72 km/h (45 mph). The driver of the Lumina proceeded into the intersection across the path of the Toyota Tundra. The front of the Tundra struck the left side aspect of the Lumina and deflected the Lumina onto the northwest corner. The severe impact was sufficient to deploy the frontal air bags in the Tundra. As the Lumina rotated and traveled to rest, the rear left unrestrained 7-year-old female passenger was most likely partially ejected from the vehicle. She sustained a diffuse axonal injury, right frontal contusion, bilateral lung contusions with pneumothorax, a left foot fracture and contusion, and multiple lacerations and abrasions. The 3-year-old male passenger who was restrained in the CSS sustained lacerations and contusions of the left basal ganglia, several skull fractures, subarachnoid hemorrhage, compression of ventricles and incisural cisterns, post-traumatic pneumocephalus, pulmonary contusions with bilateral hemo/pneumothoraces, a splenic rupture, and minor soft tissue extremity injuries from the severe left side intrusion and crash forces. The driver sustained multiple fractures of her pelvis, sacral and lumbar fractures, a Grade IV spleen laceration, fractured ribs, and contusions. The 10-year-old female front right passenger sustained hyphemia of the left eye and nasal bone fractures. All of the Lumina's occupants were transported to a regional trauma center for treatment. The 3-year-old male child was pronounced dead four hours after the crash.			
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BACKGROUND

Figure 1. Damaged 1991 Chevrolet Lumina

This on-site investigative effort focused on the fatal injury mechanisms of a 3-year-old male child passenger that was restrained in a forward-facing convertible child safety seat (CSS), which was positioned in a 1991 Chevrolet Lumina APV minivan **(Figure 1)**. The Lumina was also occupied by an unrestrained 53-year-old female driver, a restrained 10-year-old female front right passenger, and an unrestrained 7–year-old female rear left passenger. The driver brought the Lumina to a controlled stop at a four-leg intersection, which was controlled by stop signs for east/west traffic. A 2000 Toyota Tundra pickup truck with a utility trailer in tow was traveling northbound on approach to the intersection at a police-reported speed of 72 km/h (45 mph). The driver of the Lumina proceeded into the intersection across the path of the Toyota Tundra. The front of the Tundra struck the left side aspect of the Lumina and deflected the Lumina onto the northwest corner. The severe impact was sufficient to deploy the frontal air bags in the Tundra. As the Lumina rotated and traveled to rest, the rear left unrestrained 7-year-old female passenger was most likely partially ejected from the vehicle. She sustained a diffuse axonal injury, right frontal contusion, bilateral lung contusions with pneumothorax, a left foot fracture and contusion, and multiple lacerations and abrasions. The 3-year-old male passenger who was restrained in the CSS sustained lacerations and contusions of the left basal ganglia, several skull fractures, subarachnoid hemorrhage, compression of ventricles and incisural cisterns, post-traumatic pneumocephalus, pulmonary contusions with bilateral hemo/pneumothoraces, a splenic rupture, and minor soft tissue extremity injuries from the severe left side intrusion and crash forces. The driver sustained multiple fractures of her pelvis, sacral and lumbar fractures, a Grade IV spleen laceration, fractured ribs, and contusions. The 10-year-old female front right passenger sustained hyphemia of the left eye and nasal bone fractures. All of the Lumina's occupants were transported to a regional trauma center for treatment. The 3-year-old male child was pronounced dead four hours after the crash.

This crash was identified by the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) due to the use of the CSS. Contact was made with the owner of the CSS, who provided the location of the vehicle and agreed to allow the inspection of the CSS. Permission to inspect the 1991 Chevrolet Lumina was granted by a local tow yard, and an on-site investigation was assigned to the General Dynamics SCI team on April 29, 2004. The insurance company indicated that the Toyota Tundra had been sold at auction in January 2004 and was not

available for inspection. Photographs of both damaged vehicles were provided by the owner of the Lumina.

VEHILCE DATA – 1991 CHEVROLET LUMINA APV

The 1991 Chevrolet Lumina APV was identified by the Vehicle Identification Number (VIN): 1GNCU06D6T (production sequence omitted). The vehicle was a three-door minivan that was equipped with a 3.1 liter, V-6 engine, front-wheel-drive, a three-speed automatic transmission, power brakes, power steering, and a tilt steering wheel. The Lumina was configured with Goodyear Wingfoot P205/65R15 tires that were mounted on alloy wheels. The manufacturer's recommended tire pressure was unknown. The specific tire data is as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	0.0 kpa	6.4 mm (8/32")	No	Debeaded
LR	268.9 kpa (39.0 psi)	6.4 mm (8/32")	Yes	None
RF	251.7 kpa (36.5 psi)	6.4 mm (8/32")	No	None
RR	258.6 kpa (37.5 psi)	6.4 mm (8/32")	No	None

The 1991 Chevrolet Lumina was configured with front bucket seats with adjustable head restraints. Both front head restraints were in the full-down position. The second and third rows were configured with bucket seats with folding backs. The second and third row seat backs were not equipped with head restraints, and the seat backs measured 56.5 cm (22.3") in height.

VEHICLE DATA – 2000 TOYOTA TUNDRA

The 2000 Toyota Tundra pickup truck was identified by the VIN: 5TBBT4818YS (production sequence omitted). The vehicle had been sold from a salvage yard at the time of the case assignment, and could not be located for inspection. Photographs of the damaged pickup truck provided the basis of the damage assessment. The Tundra was a 4 x 4, extended-cab pickup truck that was configured with a 4.7 liter, V-8 engine, a four-speed automatic transmission, power brakes with four-wheel ABS, power steering, and a tilt steering wheel. An after-market brush guard was mounted to the front of the vehicle.

According to the tow yard operator, the Toyota Tundra was equipped with a Class III trailer hitch. At the time of the crash, the Tundra was towing a dual-axle trailer approximately 6 m (20') in length. A large John Deere tractor with a brush cutter was secured on the trailer.

CRASH SITE

This two-vehicle crash occurred during the daylight hours of November 2003 in the state of Florida. At the time of the crash, the weather was clear and the asphalt roadway surface was dry. The crash occurred at a four-leg intersection of two county roadways. Each two-lane roadway was configured with one travel lane in each direction, bordered by white fog lines at the road edges. There were no defined shoulders for either roadway. The north/south travel lanes were separated by a broken yellow centerline and the east/west travel lanes were separated by double-yellow centerlines at the legs of the intersection. Traffic flow through the intersection was controlled by stop signs for east/west traffic; located 1.4 m (4.4') above the ground. White

painted stop lines were also present on the road surface, 3 m (10') forward of each stop sign. Three series of raised asphalt rumble strips that were perpendicular to the travel lanes were present on the roadway as advanced warning devices on approach to each stop sign. The roadside environment included fields and wooded areas. The state speed limit for both roadways was 89 km/h (55 mph), although there were no speed limit signs posted on either roadway in the vicinity of the crash site. The scene schematic is included as **Figure 14** of this narrative report.

CRASH SEQUENCE

Pre-Crash

The 53-year-old driver of the Chevrolet Lumina was operating the vehicle westbound on approach to the four-leg intersection **(Figure 2)**. Although all of the child occupants were initially restrained in the vehicle, the 7-year-old female seated in the third row right position removed the safety belt prior to the crash. The driver of the Lumina brought the vehicle to a controlled stop at the intersection. According to one of the child occupants, the driver's attention may have been focused on a non-contact vehicle that was stopped on the opposing leg of the intersection waiting to continue in an eastbound direction. The driver was also attempting to find a nearby address, and may have been distracted. The driver of the Toyota Tundra pickup truck was operating the vehicle with the trailer in tow, in a northbound direction on the north/south roadway **(Figure 3)** at a police-reported speed of 72 km/h (45 mph). According to witnesses to the crash, the driver of the Lumina proceeded slowly into the intersection across the path of the oncoming Toyota pickup truck. Her pre-crash speed was unknown, however, the speedometer was fixed at 16 km/h (10 mph) at the time of the vehicle inspection.

Figure 2. Westbound approach for the 1991 Chevrolet Lumina

Figure 3. Northbound approach for the 2000 Toyota Tundra

Crash

The front of the Toyota Tundra pickup truck impacted the left side aspect of the Chevrolet Lumina minivan. The impact was severe and was sufficient to deploy the frontal air bags in the Toyota Tundra. Due to the pre-crash speed of the pickup truck and the weight of the loaded trailer, the pickup truck's momentum far exceeded that of the Lumina. The damage algorithm of the WinSMASH program computed a total delta-V of 59.0 km/h (36.7 mph) for the Lumina based on the documented crush profile. The WinSMASH-computed delta-V for the Toyota Tacoma pickup truck was 21.0 km/h (13.0 mph) based on the crush profile that was estimated from photographs. The momentum of the loaded trailer caused the Class III trailer hitch to rotate forward 90 degrees, and the front aspect of the trailer overrode the pickup truck bed.

The impact redirected the Lumina in a rapid counterclockwise (CCW) direction across the north/south travel lanes, ahead of the Toyota Tundra's trajectory, and onto the northwest corner of the intersection. During the post-impact travel, the unrestrained 7-year-old female third seat passenger was most likely partially ejected from the vehicle through the left side window opening, which had shattered at impact. The Lumina came to rest facing north on the west roadside, 6.5 m (21.3') from the road edge. As the Lumina came to rest on the roadside, it was possible that the disoriented 7-year-old child may have fallen out of the vehicle through the left rear window opening after her partial ejection and moved away from the vehicle under her own power. Although the police report indicated that the child was completely ejected, a complete ejection was not consistent with the physics of the crash, the vehicle's trajectory, and where she was found on the roadside. Based on the police measurements of the final rest of the child and the interview with the parents, she was found approximately 8.5 m (28.0') west of the southbound road edge. The Toyota Tundra continued in a tracking mode past the Lumina onto the west roadside and came to rest facing northwest 7.0 m (23.0') from the roadside.

Post-Crash

Witnesses to the crash and passers-by stopped to assist the injured occupants of the vehicles. Rescue personnel arrived on-scene and removed all of the occupants of the Lumina. According to family members, the driver of the Lumina was found lying across the front right child passenger who was found leaning against the front right door interior. The safety belt was reportedly around the child when rescue personnel opened the front right door. They removed the 10-year-old from the front right seat and subsequently removed the driver. Rescue personnel released the buckle on the CSS, rotated the tray shield upward, and removed the injured 3-year-old. The 7-year-old female child was found on the northwest roadside. All of the occupants of the Lumina were transported by helicopter to a regional trauma center. The children were admitted for treatment, but the driver was transferred and admitted to another regional trauma center, as there were only three trauma rooms at the receiving facility. The 3-year-old male child expired four hours following the crash.

VEHICLE DAMAGE

Exterior Damage – 1991 Chevrolet Lumina APV

The 1991 Chevrolet Lumina APV sustained severe left side damage as a result of the impact with the Toyota Tundra pickup truck **(Figure 4)**. The direct contact damage began 78.0 cm (30.7") rear of the left front axle and extended 180.3 cm (71.0") rearward along the left side plane. The maximum crush measured 78.1 cm (30.8") and was located 194.9 cm (76.8") rear of the left front axle. The composite body panels were fractured in multiple locations as a result of the direct contact. The left front exterior door panel was completely separated, although the reinforcement bar and latch/striker assembly showed no signs of failure. The left side exterior panel exhibited scuff marks and was separated from the left B- and C-pillars at the belt line from direct contact with the front of the Toyota Tundra. The direct contact extended 8.9 cm (3.5") vertically beyond the beltline. The left sill was crushed laterally from direct contact. The combined direct and induced damage began 45.1 cm (17.8") rear of the left front axle and

Figure 4. View of left side damage

extended 298.5 cm (117.5”) rearward along the left side plane. The severe left side crush resulted in the bowing of the Lumina.

The lateral crush resulted in the separation of the roof from the left roof side rail **(Figure 5)**. The separation began at the left B-pillar and extended rearward to the left rear corner of the roof side rail. From the separation at the B-pillar, the composite roof sustained a lateral fracture that measured 50.8 cm (20.0”) in length from the roof side rail. The maximum vertical separation of the roof measured 36.2 cm (14.3”) and was located 10.2 cm (4.0”) forward of the B-pillar centerline. The left rear body panel was deformed and fractured as a result of direct and induced damage. The lower rear aspect sustained an induced fracture as a result of the crush to the forward aspect. Six crush measurements were documented along the left side aspect at the mid-door level, and were as follows: C1 = 0.0 cm, C2 = 19.1 cm (7.5”), C3 = 63.2 cm (24.9”), C4 = 69.9 cm (27.5”), C5 = 64.8 cm (25.5”), C6 = 0.0 cm. Additional crush measurements were documented at the sill at the respective C-locations. The crush measurements along the sill were as follows: C3 = 36.8 cm (14.5”), C4 = 49.5 cm (19.5”), C5 = 49.5 cm (19.5”). Since there was no latch, pillar, or hinge failure, the mid-door and sill measurements were not averaged. The Collision Deformation Classification for the left side impact with the Toyota Tundra was 09-LPAW-5.

Figure 5. Overhead view of left side damage and roof separation

Interior Damage – 1991 Chevrolet Lumina APV

The Chevrolet Lumina sustained severe interior damage as a result of passenger compartment intrusion **(Figure 6)**. The driver’s plastic knee bolster was compressed laterally, partially separated, and fractured below the steering column. The left face of the knee bolster also exhibited a transfer from contact with the composite body panel of the left front door. The lower left quadrant of the steering wheel rim was deformed 7.0 cm (2.8”) inward and exhibited a crease in the area of the deformation as a result of direct contact with the intruded left front door. The intrusion also resulted in the lateral deflection of the steering column to the right and the 0.3 cm (1/8”) forward displacement of the right shear capsule. The left instrument panel sustained fractures and displacement due to intrusion. The left front interior door panel and armrest were fractured in multiple locations and located 7.6 cm (3.0”) left of the vehicle centerline. The driver’s seat cushion and outboard seat track were rotated 90 degrees inboard about their longitudinal axis as a result of the sill crush and lateral intrusion. The driver’s seat cushion was compressed against the front right seat. The driver’s seat back was deflected to the right and overlapped the front right seat back by 12.7 cm (5.0”). The front left floor was buckled upward 6.4 cm (2.5”) due to the lateral intrusion of the

Figure 6. View of deformation and intrusion into the driver's position

left sill. The front right sun visor mirror was fractured and the visor was in the 'down' position at the time of the vehicle inspection.

Figure 7. Longitudinal view from rear showing severe deformation and intrusion

Figure 8. View of second row bench seat showing rotation and compression of the left seat

The left aspect of the second row split bench seat was also rotated inward 90 degrees about its longitudinal axis, as a result of the sill crush and severe lateral intrusion **(Figures 7 and 8)**. The top aspect of the left seat cushion was crushed against the left side aspect of the right seat cushion. The intrusion also deflected the left seat back to the right and slightly rearward. The left seat back overlapped the right seat back by 25.4 cm (10.0"). The post-crash distance between the second row left side panel (at the beltline) and the vehicle centerline was 3.8 cm (1.5"). Specific intrusions were documented as follows:

Position	Intruded Component	Magnitude of Intrusion	Direction
FL	Left front door	55.9 cm (22.0")	Lateral
FL	Left B-pillar	64.8 cm (25.5")	Lateral
FL	Left roof side rail	27.9 cm (11.0")	Lateral
FL	Left sill	63.5 cm (25.0")	Lateral
FL	Floor	6.4 cm (2.5")	Vertical
FR	Driver's seat back	45.7 cm (18.0")	Lateral
2nd L	Left side panel	74.9 cm (29.5")	Lateral
2nd L	Left C-pillar	61.0 cm (24.0")	Lateral
2nd L	Left sill	29.2 cm (11.5")	Lateral
2nd L	Left roof side rail	24.8 cm (9.5")	Lateral
2nd C	2nd left seat cushion	13.3 cm (5.3")	Lateral
2nd C	2nd left seat back	26.7 cm (10.5")	Lateral

Position	Intruded Component	Magnitude of Intrusion	Direction
3rd L	Left rear side panel	56.4 cm (22.3”)	Lateral
3rd L	Left roof side rail	10.2 cm (4.0”)	Lateral
3rd L	Left C-pillar	22.9 cm (9.0”)	Longitudinal

Faint clear fluid-like residue was present at multiple locations on the headliner, although it could not be determined if this was related to any of the occupants. Body fluid (blood) from the 3-year-old child was present on the left side panel adjacent to the second row seats **(Figure 9)**. The transfer was located 54.6 cm (21.5”) aft of the left B-pillar and extended 19.1 cm (7.5”) rearward on the plastic panel and 13.3 cm (5.3”) rearward on the sheet metal at the beltline. The transfer began at the bottom of the window frame and extended downward 21.6 cm (8.5”).

Figure 9. View of occupant contact on the left side panel

Exterior Damage – 2000 Toyota Tundra Pickup Truck

The damage to the 2000 Toyota Tundra pickup truck was based on photographs taken at a body shop after the crash **(Figure 10)**. The pickup truck had been sold from a salvage yard and could not be located at the time of the on-site investigation. The direct contact damage extended across the entire frontal width of the Tundra. The aftermarket brush guard was deformed and the entire frontal structure was crushed rearward. The direct contact damage wrapped around the front left corner, evidenced by white paint transfers and abrasions. The combined direct and induced damage involved the entire frontal plane and measured approximately 165 cm (65”). Both front fenders sustained induced rearward buckling and rearward displacement. The hood was buckled rearward and upward. The right front tire was debeaded, and it appeared that the right front wheel may have been displaced rearward, reducing the right wheelbase. Six crush measurements were estimated along the front bumper of the Toyota Tundra as follows: C1 = 18.0 cm (7.0”), C2 = 18.0 cm (7.0”), C3 = 18.0 cm (7.0”), C4 = 18.0 cm (7.0”), C5 = 20.0 cm (8.0”), C6 = 20.0 cm (8.0”). The CDC for the frontal impact with the Chevrolet Lumina APV was 12-FDEW-1.

Figure 10. Damaged 2000 Toyota Tundra pickup truck

MANUAL RESTRAINTS – 1991 CHEVROLET LUMNIA APV

The 1991 Chevrolet Lumina was equipped with manual 3-point lap and shoulder belts for each front seat position. The driver's safety belt was configured with a sliding latch plate, a fixed D-ring, and an Emergency Locking Retractor (ELR). The driver's safety belt was not used in this crash and was found restricted in the stowed position at the time of the vehicle inspection. The front right passenger's safety belt was also configured with a sliding latch plate, fixed D-ring and ELR. Although the safety belt was used by the 10-year-old front right passenger, there was no loading evidence present on the webbing, D-ring, or latch plate. At the time of the vehicle inspection, the webbing exhibited two complete twists between the latch plate and D-ring. The webbing was not restricted, however, the retractor was sluggish and sounded somewhat noisy when the webbing was extended.

Figure 11. View of fully extended lap belt for the second row center position

The second row was configured with manual 3-point lap and shoulder belts for the outboard seating positions. The right safety belt was configured with a locking latch plate, an unknown retractor type, and was compatible with an optional full-width bench seat, which was not in use. A crease in the webbing at the D-ring supported historical non-use. The second row left safety belt was configured with an unknown retractor type and a sliding latch plate, and was restricted in a partially stowed position at the time of the vehicle inspection, due to induced damage from the impact. One twist in the webbing was present between the latch plate and fixed D-ring. The second row center seat was configured with an integrated lap belt **(Figure 11)** that was fixed to the outboard aspects of the seat cushion. The lap belt was configured with a sewn-on latch plate and an Automatic Locking Retractor (ALR) mounted on the left aspect of the cushion. The retractor and buckle were mounted slightly forward of the seat bight and the lateral distance between the retractor and buckle measured 38.1 cm (15.0") across the seat cushion. When fully extended, the length of the lap belt measured 88.9 cm (35.0"). The lap belt was used to secure the forward-facing convertible CSS in the second row center seat. There was no loading evidence present on the lap belt webbing from the CSS; however, the retractor operated in a sluggish manner at the time of the vehicle inspection.

The third row was equipped with manual 3-point lap and shoulder belts with sliding latch plates and ELR's for the two-person split bench seat. At the time of the vehicle inspection, the left side safety belt was restricted in the used position as a result of induced damage to the retractor. The right side safety belt was initially used to restrain the 7-year-old female child. The child had removed the safety belt prior to the crash, and the safety belt operated normally at the time of the vehicle inspection. Labels were present on the third row safety belts indicating that a locking clip needed to be used when installing a CSS with the third row safety belts.

CHILD SAFETY SEAT – CENTURY CONVERTIBLE

A convertible Century CSS **(Figure 12)** was positioned in the second row middle seat and secured by the lap belt with the ALR. It appeared to be consistent with a Century STE 3000, but it could not be confirmed. The labeling on the CSS had been removed, and the model number and date of manufacture were unknown. A warning on the plastic shell stated: "Do not use this car seat after December 2004." The CSS was configured with an adjustable plastic tray shield that was positioned in the full-rear position (relative to the CSS). The parents stated that the CSS was purchased new approximately seven years ago, and had been used for the other children in the family. The parents also stated that the owner's manual had been consulted when the seat was purchased, but the owner's manual location was unknown at the time of the CSS inspection. The CSS was used regularly for the 3-year-old male child, and the parents habitually installed the CSS by placing a knee into the CSS, threading the lap belt through the forward-facing belt path, pulling the belt to remove the slack into the ALR, and ensuring a tight installation. The installation was described as "tight", and they explained that the CSS would not move side-to-side when installed. The parents stated that post-crash, the CSS remained secure on the vehicle's bench seat with the lap belt.

Figure 12. Century convertible CSS

Based on an exemplar CSS in a rear-facing orientation, the CSS was rated for children who weighed less than 9 kg (20 lb) and measured less than 71 cm (28") in height. In a forward-facing orientation, the CSS was rated for children who weighed 9 – 18 kg (20 – 40 lb) and whose height was 69 – 102 cm (27 – 40"). Based on official height and weight data from the Medical Examiner and the trauma center, the child's height was 104 cm (41") and his weight as was 19 kg (42 lb), which was above the manufacturer's recommended height and weight guidelines.

At the time of the CSS inspection, the kickstand was not engaged for forward facing use. The parents indicated that the kickstand was not down at the time of the crash. The shoulder harnesses were routed through the second set of rear-facing harness slots, versus the top set of forward-facing slots. The length of the harness straps between the slots and the buckle measured 39.4 cm (15.5") and the adjustment tab on the front of the CSS was extended 9.5 cm (3.3"). The harness retainer clip was present on the harness straps 19.1 cm (7.5") above the buckle, and the parents indicated it was located at the shoulder level of the 3-year-old child. Based on the slight rearward deflection of the locking tab on the retainer clip, it appeared that the harness was historically threaded correctly through the retainer clip.

The CSS sustained minor damage as a result of the crash **(Figure 13)**. Scuff marks and abrasions were present on the left side aspect of the plastic shell, and the left arm of the tray shield was partially separated at the seams. White scuff marks from contact with the intruding left side panel of the Lumina were present on the outboard left front aspect of the CSS on the overlapping fabric. The transfers began 2.5 cm (1.0") from the front corner and measured 3.8 cm (1.5") in length and 2.5 cm (1.0") in height. Due to the lateral nature of the crash, loading to the harness straps and harness slots was minimal. Faint abrasions were present on the rear left aspects of both harness slots. Body fluid (blood) was present on the left aspect of the CSS fabric at the seat bight, on the center aspect of the CSS seat back between the top harness slots, and on the inboard aspect of the left side panel. There were no stress marks noted in the plastic shell at the time of the CSS inspection.

Figure 13. Left side view of the CSS

OCCUPANT DEMOGRAPHICS – 1991 CHEVROLET LUMINA

Driver

Age/Sex:	53-year-old female
Height:	165 cm (65")
Weight:	95 kg (210 lb)
Seat Track Position:	Appeared to be in a mid-track position at the time of the vehicle inspection
Manual Restraint Use:	Unrestrained
Usage Source:	Vehicle inspection, injury data, interview with family members
Eyewear:	Unknown
Type of Medical Treatment:	Transported by helicopter to a regional trauma center and admitted for 44 days

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Grade IV spleen laceration	Severe (544226.4,2)	Intruded left front door
Anterior right 5th rib fracture and posterior left rib fractures 8 – 12	Serious (450230.3,3)	Intruded left front door*
Bilateral sacral fractures	Serious (852800.3,6)	Intruded left front door
Left pubic symphysis fracture	Serious (853000.3,5)	Intruded left front door
Diaphragm injury, NFS	Moderate (440699.2,8)	Intruded left front door
Left L2 transverse process fracture	Moderate (650620.2,8)	Intruded left front door
L5 transverse process fracture	Moderate (650620.2,8)	Intruded left front door

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Bilateral anterior acetabular fractures with bilateral ischial tuberosity fractures	Moderate (852600.2,1) (852600.2,2)	Intruded left front door
Bilateral superior and inferior rami fractures along with parasymphyseal fractures bilaterally	Moderate (852602.2,5)	Intruded left front door
Left chest contusion	Minor (490402.1,2)	Intruded left front door
Anterior left upper arm contusion	Minor (790402.1,2)	Intruded left front door
Left buttock hematoma	Minor (890402.1,2)	Intruded left front door

Injury Source: Emergency room records/Post emergency room records

* NASS injury coding conventions require coding rib fractures with a single line of code and a single source; however, the right 5th rib fracture was most likely a result of loading against the driver's arm rest on the inboard aspect of the seat back.

Driver Kinematics

The 53-year-old female driver of the Chevrolet Lumina was unrestrained, and the driver's seat track was adjusted to a mid-track position. At impact, she initiated a lateral trajectory to the left and loaded the intruding left front door. The severe intrusion combined with her lateral motion resulted in a Grade IV spleen laceration, posterior left rib fractures 8 – 12, and a diaphragm injury. The intruding door was reinforced by the striking vehicle, and the loading against it also resulted in multiple pelvic fractures as follows: a left pubic symphysis fracture, bilateral anterior acetabular fractures with bilateral ischial tuberosity fractures, and bilateral superior and inferior rami fractures along with parasymphyseal fractures bilaterally. She also sustained an L2 transverse process fracture, an L5 transverse process fracture, bilateral sacral fractures, a left chest contusion, an anterior left upper arm contusion, and a left buttock hematoma from the loading against the intruded door. The severe intrusion rotated the driver's seat cushion about its longitudinal axis, and the driver remained displaced to the left as the vehicle rotated CCW. The driver rebounded to the right, and most likely struck the driver's armrest located on the inboard aspect of the driver's seat back, which resulted in a fracture of the anterior right 5th rib. She continued to rebound to the right against the front right child passenger. Although occupant-to-occupant contact was probable, there were no additional injuries identified on the driver as a result. The driver came to rest in the front right seat area on top of the child passenger, and against the right front door. Rescue personnel removed her from the vehicle and she was transported by helicopter to a regional trauma center. She was admitted for treatment and released after 44 days.

Front Right Child Passenger

Age/Sex:	10-year-old female
Height:	147 cm (58”)
Weight:	25 kg (55 lb)
Seat Track Position:	Appeared to be in a mid-track position at the time of the vehicle inspection
Manual Restraint Use:	Manual 3-point lap and shoulder belt
Usage Source:	Medical records, interview with family members, lack of serious injury
Eyewear:	None
Type of Medical Treatment:	Transported by helicopter to a regional trauma center and admitted for two days

Front Right Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Probable Injury Mechanism
Hyphemia, left eye	Minor (240604.1,2)	Driver’s intruded seat back/head restraint
Non-displaced bilateral nasal bone fractures	Minor (251002.1,4)	Driver’s intruded seat back/head restraint

Injury source: Emergency room records/Discharge summary

Front Right Child Passenger Kinematics

The 10-year-old female front right child passenger was seated in an upright posture with the seat track adjusted to a mid-track position. She was restrained by the manual 3-point lap and shoulder belt, although given her height and weight, the safety belt may not have been an optimal fit. At impact, she initiated a lateral trajectory to the left. She loaded the lap belt, which prevented significant movement throughout the vehicle. Given her size, her upper body may have slid laterally out of the shoulder belt, but it could not be confirmed. As she moved laterally to the left, the left aspect of her face struck the intruding driver’s seat back and head restraint, which resulted in hyphemia of the left eye and non-displaced bilateral nasal bone fractures. She was slightly displaced forward and to the left as a result of the Lumina’s rapid CCW post-impact rotation. She rebounded to the right probably struck the interior aspect of the right front door. There was no contact evidence on the door. Although there were no injuries to support contact with the driver, the child probably sustained occupant-to-occupant contact with the unrestrained driver as the driver rebounded to the right. The female child passenger was found seated with the safety belt fastened and partially under the displaced driver. Rescue personnel removed her from the vehicle. She was transported by helicopter to a regional trauma center where she was admitted for two days.

Second Row (center) Child Passenger

Age/Sex:	3-year-old male
Height:	104 cm (41”)
Weight:	19 kg (42 lb) (per trauma center)
Seat Track Position:	Fixed
Manual Restraint Use:	Forward-facing convertible CSS with a tray shield, secured by a lap belt with an ALR
Usage Source:	Vehicle inspection, injury data, interview with family members
Eyewear:	None
Type of Medical Treatment:	Transported by helicopter to a regional trauma center and expired four hours following the crash

Second Row (center) Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Lacerations and contusions of the left basal ganglia and patch linear hemorrhages in the basilar cortical stripe in the left hippocampus and on the lateral aspect of the right cerebral hemisphere	Maximum (140212.6,8) Critical (140204.5,8)	Left interior side panel intrusion
Compression of the incisural cisterns and cistern of the foramen magnum	Critical (140202.5,8)	Left interior side panel intrusion
Loss of gray-white interface throughout the cerebral hemispheres and compression of the fourth ventricle and early lateral ventricular enlargement	Severe (140664.4,9)	Left interior side panel intrusion
Skull base has a 12 cm fracture line extending across the petrous portions of both temporal lobes	Severe (150206.4,8)	Left interior side panel intrusion
Pulmonary contusions with bilateral hemo/pneumothoraces	Severe (441410.4,3)	Probable loading against left side aspect of CSS, tray shield, and harness straps
Post-traumatic pneumocephalus	Serious (140682.3,9)	Left interior side panel intrusion
Subarachnoid hemorrhage over cerebral convexities and the base of the brain	Serious (140684.3,1) Serious (140684.3,2)	Left interior side panel intrusion

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Curvilinear and stellate fracture pattern involving the lateral superior aspect of the left parietal bone which has a 14 cm fracture communicating with the frontal bone anteriorly and the medial aspect of the right parietal bone posteriorly, short linear extensions and a parallel fracture of 4.5 cm in length	Serious (150404.3,1) Serious (150404.3,2) Serious (150404.3,5)	Left interior side panel intrusion
Splenic rupture	Serious (544240.3,2)	Probable loading against left side aspect of CSS, tray shield, and harness straps
5 x 4 mm abrasion on left index finger	Minor (790202.1,2)	Tray shield
2.7 x 1.2 cm contusion on left index finger	Minor (790402.1,2)	Tray shield
10 cm superficial abrasion on the medial aspect of the right knee	Minor (890202.1,1)	Bottom aspect of the tray shield

Injury source: Emergency room records, autopsy report

Second Row (center) Child Passenger Kinematics

The 3-year-old male child was restrained in a forward-facing Century CSS on the second row center split bench seat. The CSS was restrained by the vehicle's lap belt with an ALR. Based on the CSS inspection and interview with the parents, it appeared that the CSS was tightly installed and the harness system was tight. The CSS kickstand was not engaged; therefore, the child was seated in a forward-facing, semi-reclined posture.

At impact, the 3-year-old initiated a lateral trajectory to the left and the vehicle began to rotate in a CCW direction under him. The CCW rotation allowed the left aspect of his head to become exposed forward of the left side panel of the CSS and in line with the intruding left interior side panel. The severe left side intrusion compressed the outboard aspect of the split bench seat, and contacted the outboard aspect of the CSS and outboard aspect of the tray shield. As the child moved to the left, the left side of his body loaded the left aspect of the padded plastic shell and tray shield. The loading of the child's torso against the left side of the CSS, tray shield, and harness straps resulted in pulmonary contusions with bilateral hemo/pneumothoraces and a splenic rupture. There were no indications that the child was displaced from the harness system. His head moved to the left and struck the intruded left side panel. The head strike resulted in lacerations and contusions of the left basal ganglia and patchy linear hemorrhages in the basilar cortical stripe in the left hippocampus and on the lateral aspect of the right cerebral hemisphere, compression of the incisural cisterns and cistern of the foramen magnum, a loss of gray-white interface throughout the cerebral hemispheres and compression of the fourth ventricle and early lateral ventricular enlargement, a 12 cm basilar skull fracture extending across the petrous portions of both temporal lobes, post-traumatic pneumocephalus, subarachnoid hemorrhage over

cerebral convexities and the base of the brain, and a curvilinear and stellate fracture pattern involving the lateral superior aspect of the left parietal bone which has a 14 cm fracture communicating with the frontal bone anteriorly and the medial aspect of the right parietal bone posteriorly, short linear extensions and a parallel fracture of 4.5 cm in length. The child remained displaced to the left as the Lumina rotated CCW. He sustained a 5 x 4 mm abrasion on the left index finger and a 2.7 x 1.2 cm contusion on the left index finger from probable contact with the CSS tray shield. His right knee probably contacted the bottom aspect of the tray shield, which resulted in a 10 cm superficial abrasion on the medial aspect of the right knee. He subsequently rebounded to the right and came to rest in the CSS. Body fluid (blood) was present on the Lumina's left side panel adjacent to the position of the CSS, and body fluid (blood) was also present in multiple locations on the CSS fabric from the child, who was reported by EMS to have been bleeding heavily from the mouth and nose. Rescue personnel unbuckled the latch plate, rotated the tray shield upward, and removed the child from the CSS. The child was transported by helicopter to a regional trauma center where he expired four hours following the crash.

Third Row (right) Child Passenger

Age/Sex:	7-year-old female
Height:	135 cm (53")
Weight:	23 kg (50 lb)
Seat Track Position:	Fixed
Manual Restraint Use:	Unrestrained
Usage Source:	Vehicle inspection, injury data, interview with family members
Eyewear:	None
Type of Medical Treatment:	Transported by helicopter to a regional trauma center and admitted for eight days

Third Row (right) Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Possible Injury Mechanism
Diffuse axonal injury	Critical (140206.5,8)	Head motion
Bilateral pulmonary contusions with right pneumothorax	Severe (441410.4,3)	Left rear interior side panel
Right frontal contusion, NFS	Serious (140604.3,1)	Left rear interior side panel, left C-pillar
Second through fifth left metatarsal minimally displaced diaphyseal fractures	Moderate (852200.2,2)	Left rear interior side panel (lower aspect)
Laceration over left eye	Minor (290600.1,2)	Left rear side glazing
Laceration of the left upper lip	Minor (290600.1,8)	Left rear side glazing
Multiple chest lacerations	Minor (490600.1,9)	Left rear side glazing
Sizeable parasagittal abdominal laceration on left side	Minor (590600.1,2)	Left rear side glazing

Injury	Injury Severity (AIS 90/Update 98)	Possible Injury Mechanism
Left foot contusion	Minor (890402.1,2)	Left rear interior side panel (lower aspect)
Multiple abrasions, NFS	Minor (990200.1,9)	Left rear interior side panel

Injury source: Emergency room records/Post emergency room records

Third Row (right) Child Passenger Kinematics

The 7-year-old female passenger was initially seated on the third row right seat and was restrained by the manual 3-point lap and shoulder belt. Prior to the impact, the child removed the safety belt, and her exact pre-crash posture and position in the vehicle could not be confirmed. At impact, she initiated a lateral trajectory to the left. As she was unrestrained, she most likely struck the intruded left side panel. The contact with the left side panel resulted in bilateral pulmonary contusions with right pneumothorax, second through fifth left metatarsal minimally displaced diaphyseal fractures, a left foot contusion, and multiple skin abrasions. Based on the rotation of the vehicle, it was possible that her head may have struck the left C-pillar or the left interior side panel, which resulted in a right frontal contusion. A diffuse axonal injury was most likely a result of head motion during the initial lateral movement of the child, combined with the CCW vehicle rotation. Although diffuse axonal injury could possibly result from a head strike, it is a more common result of head motion. The Lumina continued to rotate in a CCW direction as it traveled to final rest. The child remained displaced to the left as the Lumina rotated underneath her, and was probably partially ejected through the left rear window during the latter phase of the crash sequence. Contact with the fractured left rear side glazing during her partial ejection probably resulted in a laceration above the left eye, a lower lip laceration, multiple chest lacerations, and a sizeable parasagittal left abdominal laceration. As the Lumina came to rest on the roadside, the child was disoriented, and it was possible that the she may have fallen out of the vehicle through the left rear window opening after her partial ejection, and moved away from the vehicle under her own power. Although the police report indicated that the child was completely ejected, a complete ejection was not consistent with the physics of the crash, the trajectory of the vehicle, and where she was found on the roadside. She was transported by helicopter to a regional trauma center and admitted for eight days.

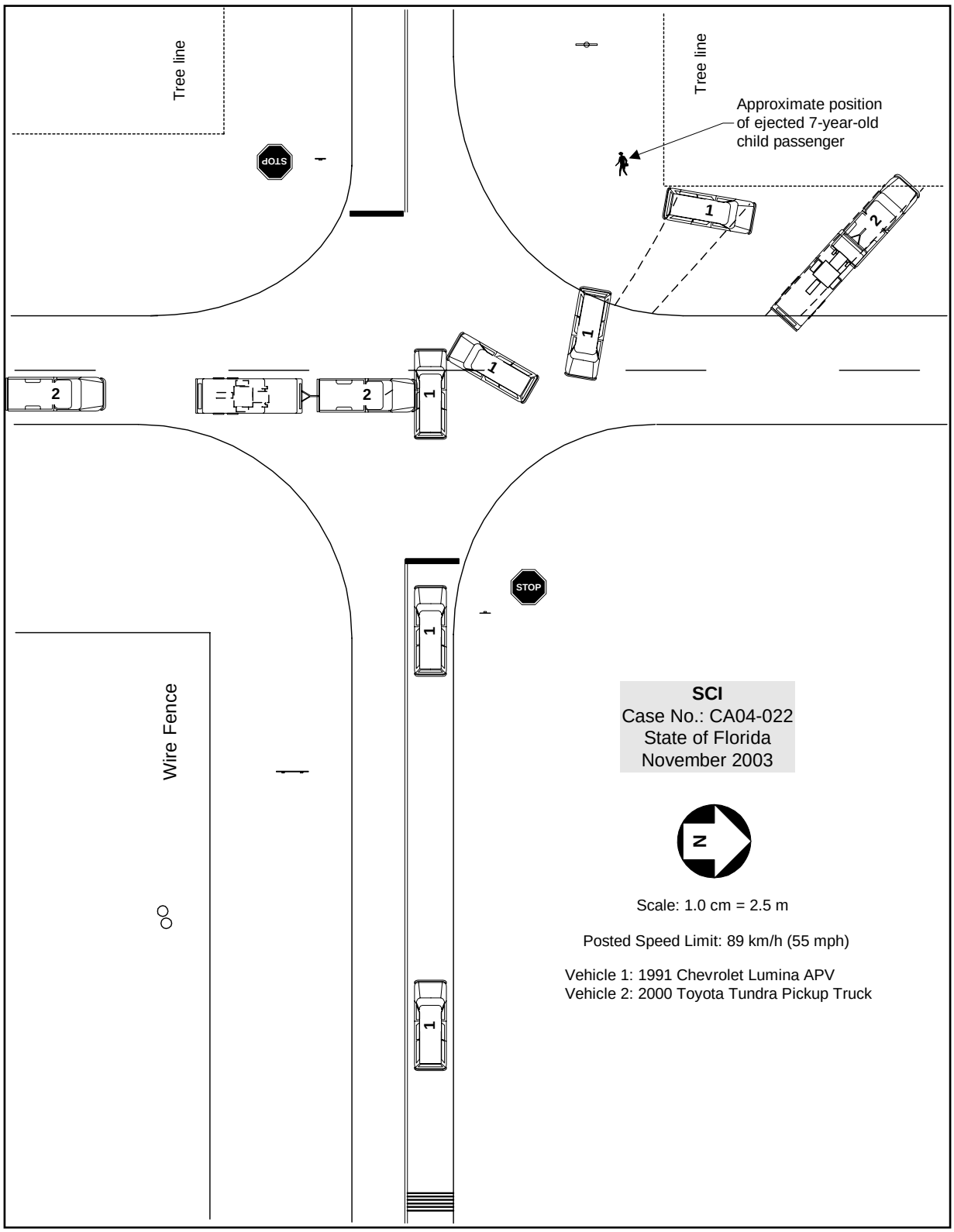

Figure 14. Scene schematic