TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

Calspan Corporation
Buffalo, New York 14225

CALSPAN ON-SITE AIR BAG/CHILD FATALITY INVESTIGATION

CALSPAN CASE NO. CA97-033

VEHICLE - 1994 FORD CROWN VICTORIA

LOCATION - OHIO

CRASH DATE - SEPTEMBER, 1997

Contract No. DTNH22-94-07058

Prepared for:

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

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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.

TECHNICAL REPORT STANDARD TITLE PAGE

1. *Report No.* CA97-033	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
		4. Weights	
5. *Title and Subtitle* Calspan On-Site Air Bag/Child Fatality Investigation Vehicle - 1994 Ford Crown Victoria Location - State of Ohio		6. *Report Date*: February, 1998	
		7. *Performing Organization Code*	
8. *Author(s)* Crash Research Section		9. *Performing Organization Report No.*	
10. *Performing Organization Name and Address* Transportation Sciences Crash Research Section Calspan Corporation P.O. Box 400 Buffalo, New York 14225		11. *Work Unit No.* 1115 (8010-8019)	
		12. *Contract or Grant No.* DTNH22-94-D-07058	
13. *Sponsoring Agency Name and Address* U.S. Department of Transportation National Highway Traffic Safety Administration Washington, DC 20590		14. *Type of Report and Period Covered* Technical Report Crash Date: September, 1997	
		15. *Sponsoring Agency Code*	
16. *Supplementary Notes* On-site investigation of a front-to-side intersection collision that resulted in deployment of the 1994 Ford Crown Victoria's front passenger air bag and subsequent death of the center front child occupant.			
17. *Abstract* This on-site investigation focused on a two vehicle intersection crash that resulted in the death of a four (4) year old female. The child was seated in the center front position of the Ford Crown Victoria. The Crown Victoria was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front passenger air bags. Only the front passenger air bag deployed as a result of the crash. The child occupant was seated unrestrained in the center position of the front seat. During the Crown Victoria's pre-crash steering and braking, the child responded by moving forward and to the right. This placed the child in a forward position, close in proximity to the mid mount front passenger air bag module. The intersection impact occurred when the front bumper of the Ford struck the left side of the Mercury Villager in a 1 o'clock/10 o'clock impact configuration. The longitudinal component of the Ford's delta V was determined to be approximately -16 to -21 km/h (-10 to -13 mph), which was of sufficient magnitude to cause the air bag to deploy. The child responded to the 1 o'clock direction of the impact forces by moving further forward into the path of the deploying front passenger air bag. Her forward position altered the deployment path of the front passenger air bag. The deploying module cover flap and air bag contacted and abraded the child's face and neck and accelerated the head rearward causing cranio cervical disarticulation and cervical cord compression (AIS 5) resulting in immediate death.			
18. *Key Words* On-site investigation, Supplemental Restraint System Air bag deployment, Fatal injuries to the center front seated child passenger		19. *Distribution Statement* General Public	
20. *Security Classif. (of this report)* Unclassified	21. *Security Classif. (of this page)* Unclassified	22. *No. of Pages* 23	23. *Price*

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LOCATION: OHIO
VEHICLE: 1994 FORD CROWN VICTORIA
CRASH DATE: SEPTEMBER, 1997

BACKGROUND

This task involved the on-site investigation of a two vehicle intersection crash that occurred in the afternoon hours of September, 1997. The crash involved a 1994 Ford Crown Victoria, 4-door sedan and a 1993 Mercury Villager minivan. The Ford Crown Victoria was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front passenger air bags. The crash caused the front passenger air bag to deploy, fatally injuring a four year old unrestrained female seated in the center position of the front seat. The child sustained cervical cord compression (AIS 5) secondary to cranial/cervical disarticulation (AIS 2), as a result of contact with the front passenger module cover flap and expanding air bag. The driver air bag in the Ford did not deploy in the crash. The National Highway Traffic Safety Administration was notified of the crash by the investigating police officer on October 3, 1997. NHTSA's Office of Defects Investigation was also notified. The Field Branch Office of the NHTSA assigned an on-site investigative effort to the Calspan Special Crash Investigation Team on the same day. The on-site inspection was conducted October 6, 1997.

SUMMARY

Inspection of the crash scene revealed the crash occurred at an urban four-leg intersection. The intersection was controlled by overhead (red/amber/green) traffic signals. The roadways were primarily northeast/southwest and north/south in direction and intersected in an angled configuration. The northeast/southwest roadway was asphalt paved and consisted of five lanes, two lanes northeast and three lanes southwest. The total width of the road was 17.2 m (56.4 ft). At the intersection, the inboard southwest lane was for left turning traffic, the center lane carried traffic through the intersection and the outboard lane was for right turning/through traffic. There was a +3% grade for southwest traffic approaching and entering the intersection. The north/south roadway was asphalt paved, 10.2 m (33.5 ft) in width and consisted of four lanes (two for each direction). At the intersection, the inboard south lane was for left turning traffic and the outboard lane was for right turning/through traffic. The speed limit on the respective roadways was 56 km/h (35 mph). At the time of the crash, it was daylight and there was no adverse weather.

Figure 1. Approach view of the Ford Crown Victoria.

The 1994 Ford Crown Victoria was traveling southwest in the center lane of the roadway as reported by

the investigating officer. The 1993 Mercury Villager was initially stopped in the south outboard lane, the second vehicle in a standing line of traffic, at a red traffic signal. Upon the change of the traffic signal to green for southbound traffic, a non-contact vehicle in front of the Mercury turned right to travel southwest and the driver of the Mercury began to accelerate southbound across the intersection. As reported by the investigating police officer, the driver of the Ford failed to stop for the (now) red traffic signal and struck the Mercury. Immediately prior to the collision, the driver of the Ford steered left and braked in an attempt to avoid the crash. The right frontal area of the Ford struck the left side of the Mercury forward of the left B-pillar. The impact configuration was 1 o'clock/10 o'clock for the Ford and Mercury respectively. The Ford rotated counterclockwise and the Mercury rotated clockwise around the Ford's right front corner. This resulted in the left rear tire of the Mercury contacting the right front fender of the Ford in a minor sideslap configuration . The vehicles then separated, with the Ford coming to rest facing southward in the south quadrant of the intersection. The driver of the Mercury steered counterclockwise and drove to rest facing northeastward in the south quadrant of the intersection, on the stop bar for northbound traffic. Refer to the crash scene schematic on page 8.

Figure 2. Front view of the Ford Crown Victoria.

The Collision Deformation Classification (CDC) of the Ford was 01-FZEW -1. The direct contact damage began 12.0 cm (4.7 in) left of center and extended 97.0 cm (38.2 in) to the front bumper's right corner. There was 2.5 cm (1.0 in) of resultant deformation at the bumper elevation across the full frontal width of the vehicle. There was additional deformation to the right front corner area of the Ford surrounding the headlamp structure that extended onto the right front corner of the hood. The Ford's entire front structure was displaced laterally (slightly) to the left causing the left front door to be jammed. A traditional engineering analysis using the principles of energy and momentum conservation was used to calculate the delta V's of the respective vehicles. Both vehicular damage and trajectory data were incorporated into this analysis. These calculations determined the (total) delta V of the Ford was 19 to 24 km/h (12 to 15 mph). The principle direction of force was in the 1 o'clock sector. The longitudinal component of the delta V was -16 to -21 km/h (-10 to -13 mph), indicating the collision severity was in the threshold for air bag deployment. An official of the Ford Motor Company indicated that it is possible that an asymmetrical deployment may occur in a crash where the severity of the collision lies in the air bag deployment threshold. The lateral delta V component was -10 to -11 km/h (-6 to -7 mph).

Figure 3. Left front view of the Mercury Villager.

The CDC of the Mercury was 10-LPEW-3. The direct damage began 49.0 cm (19.3 in) rearward of the left front axle and extended 217.0 cm (85.4 in) rearward along the left side of the Mercury. The maximum lateral deformation was 23.5 cm (9.3 in) measured at the mid-door elevation. The left front door was jammed due to the deformation. The sidewall of the left front tire was scuffed. This scuffing was matched to the tire scuffs on the front license plate of the

Ford. The sidewall of the left rear tire was also scuffed and related to the minor sideslap contact with the Ford's right front fender. The delta V of the Mercury calculated by the aforementioned analysis was 19 to 23 km/h (12 to 14 mph).

The front outboard restraint systems in the 1994 Ford Crown Victoria consisted of 3-point manual lap and shoulder belt systems with continuous loop webbings, adjustable D-rings, and locking retractors. There was a lap belt in the center front position. The vehicle was equipped with a Supplemental Restraint System (SRS) consisting of driver and front passenger air bags. The driver air bag was housed in the typical configuration in the steering wheel hub. As noted earlier there was no sign of partial/attempted deployment of the driver air bag. The front passenger air bag was a mid-mount design with a top hinged vinyl rectangular shaped cover flap. The cover flap measured 37.5 cm (14.8 in) laterally by 11.0 cm (4.3 in) vertically. The air bag was not tethered and had a single 5.5 cm (2.2 in) diameter vent port at the 2 o'clock position on the inboard side of the bag. The face of the front passenger air bag was rectangular and measured 90.0 cm (35.4 in) laterally by 53.0 cm (20.9 in) vertically. The maximum rearward extension of the air bag was 74 cm (29 in).

Figure 4: View of the front passenger air bag.

The seats in the Ford were leather, tan in color. The front seat was a 40/60 spilt bench with adjustable head restraints. There were no seat performance failures. Both seats were adjusted to a position between the middle and rear most positions. The left front seat was adjusted 5.3 cm (2.1 in) forward of the rear most position and had a total seat track travel of 19 cm (7.5 in). The right front seat was adjusted 6.5 cm (2.6 in) forward of the rear most position and had a total seat track travel of 22.5 cm (8.9 in).

During inspection of the Ford, the electrical system was energized in order to read the air bag indicator light in the vehicle's instrument cluster. Upon ignition, the indicator light was off for two seconds, illuminated (steady) for six seconds, turned off for two seconds, and then began a cycle of three flashes and then off for two seconds which then continued to repeat. According to the owner's manual the steady six second indication was normal, as the air bag system conducted its internal diagnostics. However, the repeated flashing sequence was an indicator that the air bag system required service.

There were a total of four occupants involved in this crash, two occupants in each vehicle. The driver of the Ford was a 23 year old female. She was reportedly restrained and uninjured in the crash. Inspection of the left front 3-point restraint revealed the latch plate exhibited signs of routine usage, however, there were no witness marks on the D-ring or webbing indicating usage in this crash. Due to the minor severity of the crash, no driver contacts were identified upon interior inspection of the Ford and the steering column showed no signs of compression. It did not appear that the driver was restrained. The 52 year old female driver and the 13 year old right front seated passenger of the Mercury were both reportedly restrained and uninjured.

The 4 year old child fatally injured in this crash was a female, 99.1 cm (39.0 in) height and 15.4 kg (34.0 lb) in weight. She was seated in the center front of the Ford. Post-crash the child was found unrestrained laying prone on the front seat, with her buttocks in the right front position. Her head was positioned toward the left side of the vehicle and was turned to its right. A small pooling of blood was found on the center of the front seat from the small lacerations to the child's lips and mouth. The child was removed from the vehicle by witnesses to the crash and moved to the roadside. She was held in a reclining/slumped position until the arrival of the EMS. The EMS responded to the scene arriving approximately three minutes after the crash. The EMS record reported, "the patient was unresponsive, pupils fixed, skin of face cyanotic, respirations not apparent." The child was placed on a backboard, transported and CPR was initiated. The ambulance arrived at the hospital approximately 13 minutes post-crash. The child was pronounced dead 20 to 25 minutes post-crash. The coroner reported she was wearing blue colored leggings and a white/pink/red colored shirt. The clothing was cut from the child in the emergency room and given to the family. It was not available for inspection. The child was later moved to a larger county where a contract autopsy was performed.

The police report indicated the child was restrained by the center lap belt. This information was supplied by the driver (mother). In her interview with the investigating police officer, the mother seemed to be aware of the dangers of the air bag and indicated the child typically rode in the back seat. On this occasion, however, the child wanted to sit up front. The mother believed positioning the child in the center front seat was a safe option as compared to the right front position.

The latch plate of the center lap belt did show some routine usage marks as did the lower end of the restraint webbing (near the anchor), where the webbing comes up through the seat cushion. However, the latch plate was positioned approximately 61 cm (24 in) up the webbing and the webbing exhibited no signs of latch plate movement to that location. Use of the seat belt with the latch plate adjusted in this position, as depicted in Figure 5, would not provide any means of restraint to the child occupant. On the

Figure 5: View of the front center lap belt.

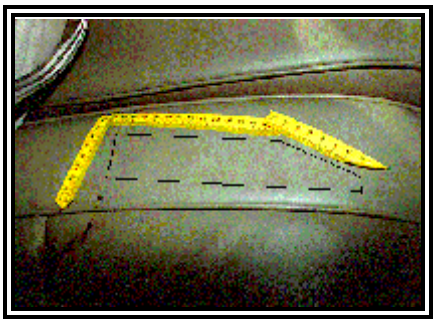

Figure 6: Fabric transfer on the front seat cushion.

surface of the leather seat cushion was a bluish fabric transfer from the child's clothing, denoted by the yellow tape in Figure 6. This transfer was 5.0 cm (2.0 in) wide by 20.0 cm (7.9 in) long, began 18.0 cm

(7.1 in) forward of the seat back and was directed forward and to the right. The presence of this transfer indicates the child's buttocks was sliding forward with respect to the vehicle, in response to the 1 o'clock principle direction of force. The medical records indicated there were no contusions or abrasions on the child's abdomen/pelvis/lower extremities indicative of lap belt usage. The physical evidence determined through the vehicle's inspection and child's kinematic pattern, discussed below, do not support the child as restrained.

The right side of the vehicle's front interior exhibited signs of interaction with the front passenger air bag. This interaction occurred due to an altered deployment path of the passenger air bag caused by the child's forward position and forward kinematics. There was a windshield fracture with an area of heavy air bag fabric transfers located 9.0 cm (3.5 in) left of the right A-pillar and 16.0 cm (6.3 in) above the instrument panel. A scuff on the top surface of the air bag 24.0 cm (9.4 in) rear of the instrument panel and 20.0 cm (7.9 in) right of the left edge of the air bag corresponded to the windshield fracture. Located 18.0 cm (7.1 in) rearward of the forward edge of the right front door on the lower surface of the arm rest was an air bag transfer 18.0 cm (7.1 in) long. A tan vinyl transfer on the face of the air bag 20.0 - 40.0 cm (7.9 - 15.7 in) down from the top and 23.0 - 31.0 cm (9.1 - 12.2 in) left of the right edge of the air bag corresponded to the door transfers.

Figure 7: Windshield fracture caused by front passenger air bag contact.

Figure 8: Air bag transfers to the lower surface of the right front door.

On the top of the passenger side module flap cover was a vertical 5.0 cm (2.0 in) pink fabric transfer, 9.5 cm (3.7 in) right of the inboard edge of the flap. Adjacent to this on the bottom surface of the bag was a 9.0 cm (3.5 in) pink fabric transfer which began 13.0 cm (5.1 in) outboard of the instrument panel. These transfers were caused by interaction with the right sleeve of the child's out-stretched arm, early in the deployment sequence. At this time, the child was positioned forward and right of center. Her right arm (arm bracing for impact) was over the top of the module cover flap. The forward body position and trajectory interfered with the deployment path of the air bag deflecting it to the right side of the vehicle.

Figure 9: Fabric transfers on the cover flap and passenger air bag.

Immediately prior to the Ford entering the intersection, the child was seated unrestrained in the center front position of the Ford, in a presumably normal posture. As the Ford entered the intersection against the red signal, the driver observed a vehicle forward and to her right initiate a right turn from the intersecting roadway. The driver then observed a second vehicle (the Mercury Villager) cross the intersection in front of her. The driver of the Ford initiated a counterclockwise steering input and began braking in an avoidance maneuver. The unrestrained child began to move forward and to the right in response to these maneuvers. This movement was evidenced by the fabric transfers on the seat cushion. The child attempted to brace herself by outstretching her right arm. Upon impact, the child's arm moved over the top of the cover flap and was positioned in close proximity to the left side of the module cover flap. As the air bag deployment initiated, a pink fabric transfer from the right shirt sleeve occurred to the left side of the cover flap and bottom of the air bag. The module cover flap contacted and abraded the right side of the child's face. The air bag then expanded under/against the child's chin and accelerated the head rearward. The rapid acceleration caused the cervical cord compression and cranio-cervical disarticulation. The child's position on the left side of the deploying air bag and motion toward the 1 o'clock direction of force loaded the air bag which altered its normal deployment path. The air bag was deflected to the right side of the vehicle, where the air bag expansion loaded the right door and windshield. This was evidenced by the respective door transfers and the windshield fracture. The child then rebounded back into the right front position where she was found.

The anatomic diagnosis of the autopsy indicated the child suffered the following:

I. Blunt impact to the head and neck.
   - A. Cranio-cervical disarticulation.
     1. Destructive spinal cord contusion.
     2. Subarachnoid hemorrhage, cervical spinal cord and cerebellum.
   - B. Ecchymosis, anterior and lateral neck.
   - C. Thymic petechia.
   - D. Lacerations of the upper lip and posterior right ear.
   - E. Tongue contusion.
   - F. Multiple cutaneous abrasions and contusions.

II. Blunt impact to the thorax.
   - A. Multiple pleural contusions.
   - B. Epicardial contusion, left atrium
   - C. Cutaneous abrasions

III. Blunt impact to the right upper extremity.

A. Contusion/abrasion of the medial surface of the proximal right upper arm.

B. Multiple contusions right ring finger, right ring finger lacerations.

The coroner ruled the cause of death as cervical cord compression secondary to cranial/cervical disarticulation secondary to a motor vehicle accident with the passenger air bag deployment listed as a contributing factor. The disarticulation occurred at the base of the skull and at the first vertebra. There were no cervical fractures.

CALSPAN ON-SITE AIR BAG/CHILD FATALITY INVESTIGATION

CALSPAN CASE NO. CA97-033

LOCATION: OHIO

VEHICLE: 1994 FORD CROWN VICTORIA

CRASH DATE: SEPTEMBER, 1997

CRASH DATA

Location:	4-leg intersection
State:	Ohio
Area/Type:	Urban
Crash Date/Time:	September, 1997/daylight hours
Investigating Police Agency:	City Police Department
Crash Type:	Sedan/Minivan, front-to-side impact configuration with subsequent sideslap
Air Bag Vehicle	
Occupant Injury Severity:	Driver - Not injured
	Center Front - Critical (AIS 5)

AMBIENCE

Viewing Conditions:	Daylight
Weather:	Clear
Precipitation:	None
Road Surface:	Dry

HIGHWAY

	Air Bag Vehicle	Vehicle #2
Type:	Local street	Local street

	Air Bag Vehicle	Vehicle #2
Number of Lanes:	5	2
Width:	17.2 m (56.4 ft)	10.2 m (33.5 ft)
Surface:	Asphalt	Asphalt
Median:	None	None
Edge:	Barrier curb	Barrier curb
Vertical Alignment:	+3% grade	Level
Horizontal Alignment:	Straight	Straight
Coefficient of Friction:	0.7 (estimated)	0.7 (estimated)
Traffic Density:	Moderate	Moderate

TRAFFIC CONTROLS

Signals:	Overhead traffic signals	Overhead traffic signals
Signs:	None	None
Markings:	Solid double yellow centerline, solid white road edge lines	Solid double yellow centerline, solid white road edge lines
Speed Limit:	56 km/h (35 mph)	48 km/h (30 mph)

VEHICLES

	Air Bag Vehicle
Description:	1994 Ford Crown Victoria, 4-door sedan
VIN:	2FALP74W8RX (production sequence deleted)
Color:	Gold
Engine:	4.6 liter, V-8
Transmission:	4-speed automatic, column mounted shifter
Steering:	Power-assisted rack and pinion

Air Bag Vehicle

Brakes:	Power assisted front disc, rear drum
Padding:	Upper and mid instrument panel, sunvisors, soft-edged steering wheel rim, door panels, door armrests, adjustable head restraint and fold-down center armrests.
Manual Restraints:	3-point lap and shoulder belt systems in the four outboard seated positions consisting of single mode inertia activated looking retractors with continuous loop belt webbing on a sliding latchplate, adjustable upper anchorages for the front seat belt systems (D-rings), center position lap belt
Automatic Restraints:	Driver and front passenger air bag Supplemental Restraint System (SRS)
Tow Status:	Towed due to vehicle damage

Vehicle #2

Description:	1993 Mercury Villager minivan
VIN:	4M2DV11W1PD (production sequence deleted)
Color:	Red
Engine:	V-6
Transmission:	Automatic
Steering:	Power-assisted
Brakes:	Power-assisted
Tow Status:	Towed due to vehicle damage

VEHICLE DAMAGE

Air Bag Vehicle

Exterior:

The 1994 Ford Crown Victoria sustained minor residual bumper deformation and structural damage to the forward third of the vehicle as a result of its impact sequence with the 1993 Mercury

Villager. The direct contact damage began 12.0 cm (4.7 in) left of center and extended 97.0 cm (38.2 in) to the right front corner. The residual crush measured along the

full width of the front bumper fascia were as follows: C^1 =2.0 cm (0.8 in), C^2=2.5 cm (1.0 in), C^3=2.5 cm (1.0 in), C^4=2.5 cm (1.0 in), C^5=2.5 cm (1.0 in), C^6=2.5 cm (1.0 in). The right front corner area of the Ford was deformed around the headlamp structure that extended onto the right front corner of the hood. The vehicle's entire structure forward of the A-pillars was displaced laterally (slightly) to the left. This structural deformation caused the left front door to be jammed. The principle of energy and momentum conservation were used to reconstruct the crash. The total delta V of the Ford was determined to be 19 to 24 km/h (12 to 15 mph), with a longitudinal component of -16 to -21 km/h (-10 to -13 mph). The lateral delta V component was -10 to -11 km/h (-6 to -7 mph).

CDC: 01-FZEW-1

Repair Cost: Estimated $8000

Interior:

Interior damage of the Ford Crown Victoria was limited to deployment of the Supplemental Restraint System and occupant contact points located primarily on the passenger side of the vehicle. There was no intrusion into the interior space of the vehicle caused by the exterior forces of the crash. Figures 10 and 11 below depict the interior contact evidence.

Minor fabric abrasions were located on both the left and right sun visors. The left sun visor exhibited a 2.0 cm (0.8 in) vertical abrasion, 2.5 cm (1.0 in) from the visors right edge. The abrasion on the right sun visor was oriented vertically, 3.0 cm (1.2 in) long, and located 24.5 cm (9.6 in) right of the left edge. The center mirror was displaced which caused a windshield fracture located 10.0 cm (3.9 in) left of center and 13.0 cm (5.1 in) below the windshield header. A plastic transfer from the left edge of the mirror was located adjacent to the fracture site. A 2.0 cm (0.8 in) scuff was identified in the lower right corner on the back (non-mirrored) surface. The fracture and scuff were caused by rebound contact with the child occupant's right hand/forearm.1

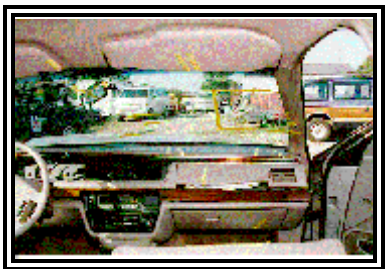

Figure 10: Interior view of the Ford Crown Victoria.

The right center portion the windshield exhibited 3 separate air bag scuffs. The first scuff was 4.0 cm (1.6 in) in length, located 8.0 cm (3.1 in) above the instrument panel and 72.0 cm (28.3 in) left of the right of the A-pillar. The second scuff was 5.0 cm (2.0 in) long and was located 13.0 cm (5.1 in) above the instrument panel and 86.5 cm (34.1 in) left of the A-pillar. The third scuff was 6.0 cm (2.4 in) long located 14.0 cm (5.5

in) above the instrument panel and 80.0 cm (31.5 in) left of the A-pillar. The right edge of the windshield was scuffed and fractured by the altered deployment path of the passenger air bag. The fracture was located 9.0 cm (3.5 in) left of the right A-pillar and 16.0 cm (6.3 in) above the instrument panel. A 7.0 cm (2.8 in) square area of heavy air bag fabric transfers was located adjacent to the fracture site. The right A-pillar exhibited 2 small air bag scuffs. The first was 4.0 cm (1.6 in) in length located 22.0 cm (8.7 in) from the base of the pillar. The second scuff was a 1.0 cm (0.4 in) square area located 25.0 cm (9.8 in) from the base of the pillar.

The leading edge of the instrument panel was scuffed in two places caused by contacts with the front passenger air bag module flap in the deployment. A 3.0 cm (1.2 in) scuff located 52.0-55.0 cm (20.4-21.7 in) left of the right edge was caused by the left edge of the module flap. Two parallel scuffs 7.0 cm (2.8 in) in length (from the leading edge of the instrument panel forward) were located 12.0 cm (4.7 in) and 15.5 cm (6.1 in) left of the instrument panel's right edge, respectively. These scuffs were caused by the right edge of the cover flap. The module cover flap exhibited a 5.0 cm (2.0 in) vertical pink fabric transfer located 9.5 cm (3.7 in) right of the left flap edge, (referenced earlier in this report).

The altered deployment of the front passenger air bag also scuffed the right front door glazing and the lower aspect of the door. A 12.0 cm (4.7 in) scuff was located 46.0 cm (18.1 in) forward of the trailing edge of the glazing and 19 cm (7.5 in) above the glazing's lower edge. A scuffed 2.0 cm x 1.0 cm (0.8 in x 0.4 in) area was located 28.0 cm (11.0 in) forward of the glazing's trailing edge and 36.0 cm (14.2 in) above the lower edge. A 3.0 cm (1.2 in) air bag transfer was located on the upper aspect of the door (near the lock), 7.0 cm (2.8 in) forward of the door's trailing edge. Located 18.0 cm (7.1 in) rearward of the forward edge of the right front door on the lower surface of the arm rest was an air bag transfer 18.0 cm (7.1 in) long. (Refer to Figure 11 at the right.) An air bag fabric transfer 4.0 cm (1.6 in) in length was located on the leading edge of the B-pillar 29.5 cm (11.6 in) above the floor, 66.0 cm (26.0 in) rearward of the instrument panel.

Figure 11: Right front door contacts.

The center portion the spilt front bench seat exhibited evidence of occupant interaction. A blue fabric transfer (identified earlier in this report as Figure 6) was 5.0 cm (2.0 in) wide by 20.0 cm (7.9 in) long, began 18.0 cm (7.1 in) forward of the seat back and was directed forward and to the right. The presence of this transfer indicates the child was sliding forward with respect to the vehicle, in response to the 1 o'clock principle direction of force. Two areas of blood were located on the front seat and identify the probable final rest location of the child occupant's head. A trail of dried blood 14.0 cm (5.5 in) in length was located 9.0-19.0 cm (3.5-7.5 in) forward of the seat back and 12.0-21.0 cm (4.7-8.3 in) right of the left edge of the seat. An area 7.0 x 6.0 cm (2.8 x 2.4 in) of dried blood and fluid was located 16.0 cm (6.3 in) forward of the seat back and 30.5 cm (12.0 in) right of the left edge of the seat. Blood/bodily fluid droplets were also identified on

the headliner. The droplets formed an arc 41.0 cm (16.1 in) in length that began 50.0 cm (19.7 in) rearward of the front header and 54.0 cm (21.3 in) left of the right roof rail. A droplet 1.0 x 1.0 cm (0.4 x 0.4 in)was located 79.0 cm (31.1 in) rearward of the front header and 47.0 cm (18.5 in) left of the right roof rail. These fluids were deposited during the rebound phase of the occupant's trajectory.

Vehicle #2

Exterior:

The 1993 Mercury Villager sustained contact damage long the left side of the vehicle in the intersection collision with the Ford. The direct damage began 49.0 cm (19.3 in) rearward of the left front axle and extended 217.0 cm (85.4 in) rearward along the left side of the Mercury. The maximum lateral deformation was 23.5 cm (9.3 in) measured at the mid-door elevation. The left front door was jammed due to the deformation. The sidewall of the left front tire was scuffed. This scuffing was matched to the tire scuffs on the front license plate of the Ford. The sidewall of the left rear tire was also scuffed and related to the minor sideslap contact with the Ford's right front fender

CDC: 10-LPEW-03

Repair Cost: Estimated $6000

AUTOMATIC RESTRAINT SYSTEM

The 1994 Ford Crown Victoria was equipped with a Supplemental Restraint System (SRS) that consisted of driver and right front passenger air bags, impact sensors and diagnostic module. Only, the right front passenger air bag deployed as a result of the intersection impact sequence with the 1993 Mercury Villager. The driver air bag did not deploy. Reconstruction of the crash indicated the longitudinal delta V of the Ford was in the threshold required for air bag deployment. The Safety Office of the Ford Motor Company indicated that it is possible that an asymmetrical deployment may occur in a crash where the severity of the collision lies in the air bag deployment threshold. The manufacturer indicated that there are small differences in the electrical resistance between the driver and front passenger air bag modules. And furthermore, a threshold deployment generates a relatively weak electrical signal. An asymmetrical deployment will occur because the magnitude of the electrical signal is only great enough to overcome the lesser air bag module resistance path.

The two front impact sensors were mounted to the upper radiator support immediately behind the front grille and headlamps. The sensors were located in the impact zone for this crash and were undamaged. The left and right sensors were identified by the serial numbers of 5A12941866 and 5A13644869, respectively. During inspection of the Ford, the electrical system was energized in order to read the air bag indicator light in the vehicle's instrument cluster. Upon ignition, the indicator light was off for two seconds, illuminated (steady) for six seconds, turned off for two seconds, and then began a cycle of three flashes and then off for two seconds which then continued to repeat. According to the owner's manual the steady six second indication was normal, as the air bag system conducted its internal diagnostics. However, the repeated flashing sequence was an indicator of a problem with the air bag system and service was required.

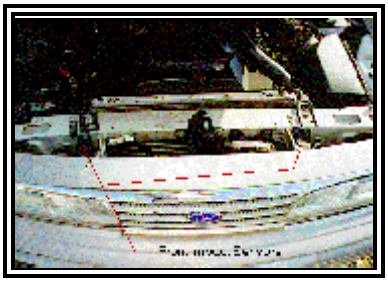

Figure 12: Air bag sensor locations.

The driver's side air bag was housed in the typical configuration in the center hub of the 4- spoke steering wheel. The spokes were located at the 3, 4, 8 and 9 o'clock sectors. The spokes contained the activation and control switches for the horn and cruise control. The steering wheel rim was not deformed. The driver air bag module cover flap was designed in the H-configuration. The center tear seam was 21.0 cm (8.3 in) wide. The upper and lower flaps were 10.5 cm (4.1 in) and 9.5 cm (3.7 in) in height, respectively.

The right front passenger air bag was housed in a mid-mount configuration on the right side of the instrument panel. The module cover flap was a rectangular, measured 37.5 cm (14.8 in) by 11.0 cm 4.3 in) width by height and was comprised of a rubberized/vinyl material approximately 3.0 mm (0.12 in) thick. The aforementioned 5.0 cm (2.0 in) pink transfer, Figure 9, located 9.5 cm (3.7 in) right of the left edge was the only evidence on the exterior of the cover flap. The following designation was embossed onto the interior surface of the cover flap:

91273HCAV#2

DYM 100

EN53 PSIR DOOR

DIT #F093-503

SAE-TEEE

04259433

The right front passenger air bag deployed as designed from the air bag module housed on the right side of the instrument panel. The face of the air bag was rectangular and measured 90 cm (35 in) by 53 cm (21 in), width by height, in its deflated state. The air bag was not tethered and was vented by a single 5.5 cm (2.2 in) diameter port and was located at the 2 o'clock sector on the inboard side panel of the bag. The air bag extended 52 cm (20 in) from the module in its approximated inflated state and could be fully extended 73 cm (29 in) pulled taut. On the top

surface of the air bag was a scuff located 24.0 cm (9.5 in) rearward of the instrument panel and 20.0 cm (7.9 in) right of the inboard (left) edge of the air bag. This scuff matched to the scuff and fracture site located on the right aspect of the windshield, indicating altered deployment path.

Two tan colored vinyl transfers 20.0 cm (7.9 in) length were located on the face of the air bag. These arc shaped transfers were located approximately 20.0 cm (7.9 in) from the top surface of the air bag and 23.0 cm (9.1 in) and 31.0 cm (12.2 in) left of the outboard (right) edge of the bag. The transfers are depicted in Figure 13. These transfers were matched directly to the scuffs on the lower aspect of the right front door, Figure 14. On the inboard side panel of the air bag, 18.0 cm (7.1 in) forward of the instrument panel and 10.0 cm (3.9 in) from the top surface of the bag, was a blue fabric transfer. Refer to Figure 15. The transfer was 18.0 cm (7.1 in) in length. This transfer was evidence of possible contact with the blue leggings of the child. On the bottom surface of the bag was the aforementioned 9.0 cm (3.5 in) pink fabric transfer which began 13.0 cm (5.1 in) rearward of the instrument panel, Figure 9. This transfer was attributed to the red/pink/white shirt the child was wearing. The location of this transfer of the bottom surface of the air bag indicated that the child occupant was positioned forward in the very early stages of the deployment sequence.

Figure 13: Vinyl transfers to the face of the air bag.

Figure 14: Match-up of the transfer to the right front door.

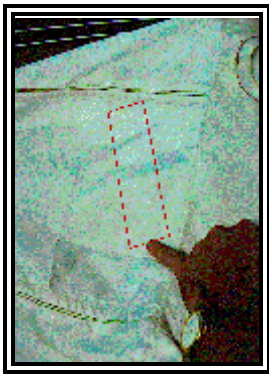

Figure 15: Blue transfer to the air bag inboard side panel.

MANUAL RESTRAINTS

The 1994 Ford Crown Victoria was equipped with manual 3-point lap and shoulder belts in the four outboard seated positions and a 2-point lap belt for the center seated positions. The front outboard seat belt systems consisted of a continuous loop lap and shoulder belt webbing with a sliding latchplate. A single mode inertia activated looking retractor was mounted in the base of each B-pillar. The-3 point belt systems utilized an adjustable upper anchorage (D-ring). The driver and right front D-rings were adjusted to a point that was in the middle of the adjustment range. The police report indicated that the driver was restrained. Inspection of the left front 3-point restraint revealed the latch plate exhibited signs of routine usage consistent with the age of the

vehicle. There were no witness marks on the D-ring or webbing indicating usage in this crash however. Due to the minor severity of the crash, no driver contacts were identified upon interior inspection of the Ford and the steering column showed no signs of compression. It did not appear that the driver was restrained.

The four year old child passenger was seated in the center front position and the driver (mother) reported to the investigating police officer she was restrained by the lap belt. The latch plate of the center lap belt did show some routine usage marks as did the lower end of the restraint webbing (near the anchor), where the webbing comes up through the seat cushion. However, the latch plate was positioned approximately 61 cm (24 in) up the webbing and the webbing exhibited no signs of latch plate movement to that location. As mentioned in the summary section, Figure 5 depicts the position of the latch plate as found during the inspection. Use of the seat belt with the latch plate adjusted in this position would not provide any means of restraint to the child occupant. On the surface of the leather seat cushion was a bluish fabric transfer from the child's clothing. The presence of this transfer indicates the child's buttocks was unrestrained, sliding forward with respect to the vehicle, in response to the 1 o'clock principle direction of force. The medical records indicated there were no contusions or abrasions on the child's abdomen/pelvis/lower extremities indicative of lap belt usage. The physical evidence determined through the vehicle's inspection and child's kinematic pattern indicated the child was unrestrained in this crash.

COLLISION SEQUENCE

Pre-Crash:

Immediately prior to the crash, the 1994 Ford Crown Victoria was being operated southwestbound by the unrestrained 23 year old female driver. The four year old child passenger was seated unrestrained in the center front position. It was the intention of the driver to travel an unknown distance beyond the intersection to her beautician (hair dresser) located on this same roadway.

On the approach to the four-leg intersection where the crash occurred, the Ford was reportedly operating in the center southwestbound lane. This lane was for straight through traffic, traveling through the intersection. The driver reported that the vehicle was being operated within the 56 km/h (35 mph) speed zone. Reconstruction of the crash has determined the impact speed of the Ford was approximately 40 to 48 km/h (25 to 30 mph). The dynamics of the collision do not indicate there was any element of excessive speed in this crash.

The 1993 Mercury Villager was stopped at a red traffic signal, the second vehicle in a line of standing traffic on the intersecting roadway. It was the intention of the 52 year old female driver to continue southbound through the intersection. The right front seated passenger on-board the Mercury was a 13 year old female. Both occupants in the Mercury were restrained. Upon the

change of the traffic signal to green for southbound traffic, the non-contact vehicle in front of the Mercury turned right to travel southwest and the driver of the Mercury began to accelerate southbound across the intersection. The southwestbound Ford failed to stop for the (now) red traffic signal and entered the intersection. The driver of the Ford stated her attention was drawn to a vehicle forward and to her right that turned it to its right and was proceeding southwestbound. She then stated that she saw the Mercury Villager in front of her and turned her vehicle to the left in an attempt to avoid the collision. Reconstruction of the crash also indicated that the Ford was braking.

Crash:

The center and right frontal area of the Ford Crown Victoria impacted the left side of the Mercury Villager in a 1 o'clock/10 o'clock impact configuration. The impact caused the Mercury to rotate clockwise around the right front corner of the Ford and the Ford rotated (slightly) counterclockwise. The vehicles then contacted in a minor side slap configuration with the left rear tire of the Mercury scuffing the right front fender area of the Ford.

Reconstruction of the crash using the principles of energy and momentum conservation determined the total velocity change (delta V) of the Ford was 19 to 24 km/h (12 to 15 mph). The longitudinal component of the Ford's delta V was -16 to -21 km/h (-10 to -13 mph). The lateral delta V component was -10 to -11 km/h (-6 to -7 mph). The collision severity was within the deployment threshold range and caused the deployment of the right front passenger air bag. The delta V of the Mercury was 19 to 23 km/h (12 to 14 mph).

Post-Crash:

Final Rest - The Ford came to rest facing southward, in the southwest quadrant of the intersection. The Mercury was steered counterclockwise, drove around the front of the Ford and came to rest on the stop bar on the south side of the intersection as depicted in Figure 16.

Driver Activities - Immediately following the crash the driver of the Ford Crown Victoria observed that her four year old daughter was not responding and she began to call for help. The investigating officer was (coincidentally) working a routine traffic stop several hundred yards from the intersection. The officer responded to the scene. En-route, he saw several witnesses respond and begin to render assistance to the child. The officer approached the left side of the Ford and spoke to the driver who remained inside the vehicle.

Rescue Activities - Witnesses to the crash responded to the right side of the Ford and found the child lying prone on the front seat. Her buttocks were on the right front seat and her head was positioned toward the driver. She was not restrained by the center lap belt. The child was unconscious and bleeding from the mouth. Several witnesses removed the child and held her in a reclining/slumped position until the arrival of the EMS. The EMS responded to the scene approximately three minutes post-crash. The EMS record reported, "the patient was unresponsive, pupils fixed, skin of face cyanotic, respirations not apparent." The child was placed on a backboard, transported and CPR was initiated. The ambulance arrived at the hospital approximately 13 minutes post-crash. The child was pronounced dead 20 to 25 minutes post-

crash. The driver of the Ford who was not injured was transported to the hospital via a second ambulance.

Scene Clearance - The Ford Crown Victoria and the Mercury Villager sustained disabling damage and were towed from the scene of the crash following the on-scene police investigation. The Ford was impounded by the local police department and retained for SCI inspection. The Mercury was available for inspection at a local auto dealership.

DEMOGRAPHICS/OCCUPANT DATA

Air Bag Vehicle	Driver	Child Occupant
Age:	23 year old female	4 year old female
Height:	Unknown	99.1 cm (39.0 in)
Weight:	Unknown	15.4 kg (34.0 lb)
Manual Restraint Usage:	None	None
Usage Source:	Vehicle inspection	Vehicle inspection
Eyewear:	Unknown	None
Mode of Transport From Scene:	Ambulance	Ambulance
Type of Medical Treatment:	Declined medical attention	Transported to a the Emergency Room of a local hospital where she was pronounced deceased approximately 20 to 25 minutes post-crash.
Vehicle Familiarity:	Familiar, purchased used 2 to 3 months prior to the crash	
Route Familiarity:	Very familiar, resident of area	
Trip Plan:	To hair dresser	

DRIVER INJURIES

Injury	Injury Severity (AIS-90)	Injury Mechanism
None	N/A	N/A

DRIVER KINEMATICS

The driver of the Ford Crown Victoria was seated unrestrained in a presumed normal posture and was operating the vehicle in the center southwestbound lane on the roadway. The seat was positioned in a mid ro rear track position, 5.25 cm (2.1 in) forward of the rear most position. It is probable the driver braced herself for the crash. Upon impact, the driver exhibited a forward trajectory in response to the collision forces. Due to the relative minor nature of the impact, the driver was able to prevent herself from significant contact to any

of the vehicle's interior structures. No evidence of occupant contact was found on the left side of the interior and the driver was not injured.

CHILD OCCUPANT INJURIES

Injury	Injury Severity (AIS-90)	Injury Mechanism
Cervical spinal cord contusion with disarticulation at the base of the skull and first vertebra.	Maximum (640234.6,6)	Front Passenger Air Bag
Multi-focal pleural contusions posterior and lateral aspects right lung and lateral aspect left lung.	Serious (441402.3,3)	Front Passenger Air Bag
Epicardial contusion on the posterior surface of the left atrium	Serious (441002.3,4)	Front Passenger Air Bag
Acute sub-arachnoid hemorrhage cerebellum and cervical spinal cord	Serious (140466.3,6)	Front Passenger Air Bag
38 mm x 25 mm (1-1/2"x1") abrasion over left medial submental and left upper medial neck regions	Moderate (390202.1,2)	Front Passenger Air Bag
20 cm x 10 cm (8"x4") ecchymosis around the anterior and lateral neck and over the superior and anterior right shoulder	Moderate (790402.1,1)	Front Passenger Air Bag
16 mm x 6 mm (5/8"x1/4") abrasion over the left lateral forehead	Minor (290202.1,7)	Front Passenger Air Bag
10 mm x 6 mm (3/8"x1/4") abrasion over the right lateral forehead	Minor (290202.1,7)	Front Passenger Air Bag
10 mm x 5 mm (3/8"x3/16") abrasion over the right upper orbital rim	Minor (297202.1,1)	Front Passenger Air Bag
3 mm x 3 mm (1/8"x1/8") abrasion over the right temple	Minor (190202.1,1)	Front Passenger Air Bag
25 mm x 16 mm (1"x5/8") abrasion over the right lateral zygoma	Minor (290202.1,1)	Front Passenger Air Bag
3 mm x 3 mm (1/8"x1/8") abrasion over the middle of the upper lip	Minor (292020.1,8)	Front Passenger Air Bag

Injury	Injury Severity (AIS-90)	Injury Mechanism
10 mm x 2 mm (3/8"x1/16") laceration over the right lateral margin upper lip	Minor (290602.1,8)	Front Passenger Air Bag
6 mm x 3 mm (1/4"x1/8") laceration over the upper lip frenulum	Minor (290602.1,8)	Front Passenger Air Bag
22 mm x 10 mm (7/8"x3/8") abraded contusion over the lateral right lower lip	Minor (290202.1,8) Minor (290402.1,8)	Front Passenger Air Bag
three <3 mm (1/8") abrasions over the middle and left lateral lower lip	Minor (290202.1,8)	Front Passenger Air Bag
10 cm x 3.8 cm (4"x1-1/2") irregular abrasion centered over the right mandible	Minor (290202.1,8)	Front Passenger Air Bag
Three lacerations 3 mm to 16 mm (1/8" to 5/8") over the posterior surface right ear	Minor (290602.1,1)	Front Passenger Air Bag
13 mm x 13 mm (1/2"x1/2") contusion over the right mastoid region	Minor (190402.1,1)	Front Passenger Air Bag
6.4 cm x 5 cm (2-1/2"x2") hemorrhage into the connective tissue of the scalp over the midline of the vertex	Minor (190402.1,9)	Front Passenger Air Bag
16 mm x 10 mm (1/2"x3/8") contusion over the right lateral upper neck	Minor (390402.1,1)	Front Passenger Air Bag
38 mm x 19 mm (1-1/2"x3/4") abrasion over the right-anterior lateral lower neck	Minor (390202.1,1)	Front Passenger Air Bag
22 mm x 10 mm (7/8"x3/8") abrasion over the left sterno-clavicular joint	Minor (790202.1,2)	Front Passenger Air Bag
9.8 cm x 5 mm (3-7/8"x3/16") interrupted abrasion over the left anterior para-midline sternum	Minor (490202.1,4)	Front Passenger Air Bag
5 mm x 3 mm (3/16"x1/8") abrasion over the right upper areola skin margin	Minor (490202.1,1)	Front Passenger Air Bag

Injury	Injury Severity (AIS-90)	Injury Mechanism
3 cm x 1 cm (1-1/4"x1/2") abraded contusion over the medial surface of the proximal right upper arm	Minor (790202.1,1) Minor (790402.1,1)	Front Passenger Air Bag Module Cover Flap
3 cm x 10 mm (1-1/4"x3/8") contusion over the ulnar aspect of the right hand	Minor (79402.1,1)	Sunvisor
1.2 cm (1/2") superficial laceration dorsum of the distal right 4th finger	Minor (790602.1,1)	Sunvisor
6 mm (1/4") superficial laceration dorsum of the distal right 5th finger	Minor (790602.1,1)	Sunvisor
Multiple 3 mm to 19 mm (1/8" to 3/4") contusions over the dorsal right four fingers	Minor (790402.1,1)	Sunvisor
Five contusions <12 mm (<1/2") over the anterior surface of both knees and both lower legs	Minor (890402.1,3)	Glove Box door

CHILD OCCUPANT KINEMATICS

The four year old child passenger was seated in the center front position of the Ford Crown Victoria in a presumed normal posture. She was not restrained by the available manual 2-point lap belt. The right side of the 60/40 split bench seat was adjusted to a mid to rear track position 6.5 cm (2.6 in) forward of the rear most position. The child was reportedly wearing a red/pink/white shirt and blue colored leggings.

The driver of the Ford steered the vehicle counterclockwise and braked in an attempt to avoid the impending impact. The child passenger responded to the vehicle's maneuvers by initiating a forward and right trajectory, with respect to the vehicle. This kinematic pattern was evidenced by the blue fabric transfer from the child's leggings to the vehicle's seat cushion. The initial stages of the 1 o'clock trajectory, from the center position in the vehicle, directed the child toward the left side of the front passenger air bag module. The child attempted to brace herself in this sequence by out-stretching her right arm. This positioned the arm near the left aspect of the front passenger air bag module cover flap. Upon impact with the Mercury Villager, the child responded to the 1 o'clock direction of the impact forces by moving further forward and right. This positioned the right side of the child's face/head near the outer limit of the mid mount air bag module's left aspect and her right arm over the cover flap.. The impact caused only the front passenger air bag to deploy.

The cover flap rotated open and the red/pink/white shirt was in contact with the cover flap and the bottom surface of the air bag in the early stages of the deployment sequence. This contact was

evidenced by the pink fabric transfer Figure 9 and the abraded contusion of the medial surface of the right upper arm. The deploying air bag contacted the right side of the child's face which resulted in lacerations to her lips and the large abrasion centered on the mandible. The expanding front passenger air bag membrane contacted the right lateral upper neck and expanded onto the head and the right lower neck and right shoulder evidenced by the extensive ecchymotic region. The expanding air bag accelerated the child's head in a rearward direction. The rapid acceleration due to the deployment resulted in disarticulation at the base of the skull and at the first vertebra. There were no cervical fractures. A circumferential cord stricture and hemorrhage an unspecified cervical region was revealed by the autopsy.

The child's forward kinematic trajectory during the deployment sequence caused the child to load the air bag and alter its deployment path to the right. The altered air bag expansion contacted and fractured the right side of the windshield (Figure 7), and contacted and scuffed the right front window glazing and the lower aspect of the right front door (Figures 11, 13 and 14).

The child rebounded back into the right front seat where she was found. As the child began to move rearward, it is probable that her leggings contacted the inboard side panel of the deployed air bag causing the aforementioned transfer (Figure 15). Additionally, the child's lower extremities contacted the glove box door resulting in the small contusions to the region. Her rebound trajectory likely caused her left hand/forearm to contact the back (non-mirrored) side of the center mirror. This contact displaced the left side of the mirror into the windshield, causing it to fracture. Her right hand and forearm rotated up and abraded the right sunvisor causing the minor lacerations and contusions to the right hand and fingers. The child came to rest with her buttocks in the right front position and with her head toward the seat's center position. Her head was turned to its right, with the mouth near the small pooling of blood found on the seat cushion.