

**TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION**

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ON-SITE DRIVER AIR BAG DEPLOYMENT/CHILD FATALITY INVESTIGATION

VERIDIAN CASE NO. CA00-011

VEHICLE: 1995 MERCURY GRAND MARQUIS

LOCATION - MASSACHUSETTS

CRASH DATE - APRIL 2000

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

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

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17. <i>Abstract</i> <p>This on-site investigation focused on the fatal injury mechanisms of a 9 year old male seated in the front left of a 1995 Mercury Grand Marquis. The child was given permission to drive the vehicle in the family's driveway. The 9 year old driver accelerated the Mercury forward and struck an earthen hill side at the end of the driveway. The vehicle was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front right passenger air bags. The air bags deployed as a result of the above-threshold impact. The child and a 71 year old female front center passenger were unrestrained at the time of the crash. The deploying driver air bag struck the child under the chin resulting in a fatal basilar skull fracture. The female passenger sustained only minor abrasions and contusions in the crash event.</p> <p>The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) became informed of the crash through the local news media on April 4, 2000. NHTSA subsequently assigned an on-site investigation of the crash to Veridian SCI the same day. Cooperation with the local investigating authorities was established. The vehicle was in the possession of the family and held pending SCI investigation.</p>			
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BACKGROUND

This on-site investigation focused on the fatal injury mechanisms of a 9 year old male seated in the front left of a 1995 Mercury Grand Marquis. The child was given permission to drive the vehicle in the family's driveway. The 9 year old driver accelerated the Mercury forward and struck an earthen hill side at the end of the driveway. The vehicle was equipped with a Supplemental Restraint System (SRS) that consisted of driver and front right passenger air bags. The air bags deployed as a result of the above-threshold impact. The child and a 71 year old female front center passenger were unrestrained at the time of the crash. The deploying driver air bag struck the child under the chin resulting in a fatal basilar skull fracture. The female passenger sustained only minor abrasions and contusions in the crash event.

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SUMMARY

Crash Site

This single vehicle crash occurred in the early evening hours of April, 2000. At the time of the crash, it was daylight and the weather was not a factor. The crash occurred on private property, in the family's driveway. **Figure 1** is a trajectory view looking eastward along the driveway. The driveway consisted of packed dirt and gravel and was predominately east/west in direction. It measured approximately 43 m (141 ft) in total length. The driveway descended from the road with a negative grade of approximately 10 degrees for 25 m (81 ft) and then leveled out into a parking area measuring 18 m (60 ft) in length. The driveway terminated at the base of a hill side embankment that bordered the property. The slope of the embankment was an estimated 50 degrees. **Figure 2** is a view of



Figure 1: Trajectory view looking along the driveway.

the embankment (point of impact) taken during the police investigation.

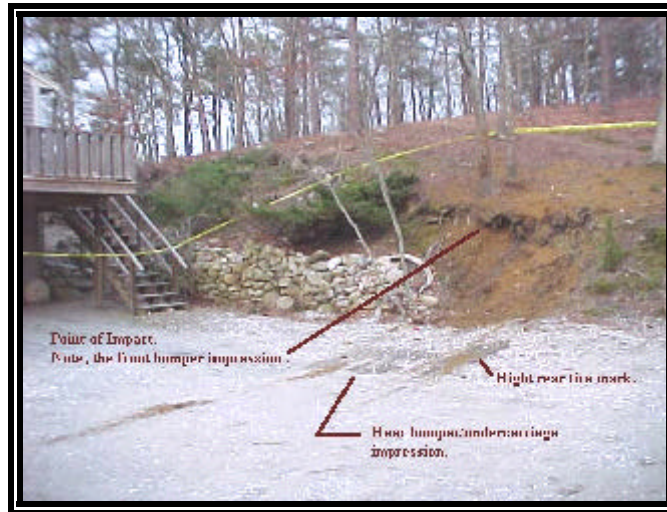


Figure 2: On-scene photograph of the point of impact.

Pre-Crash

Reportedly, the 9 year old male and his 71 year old grandmother were returning home after going out for ice cream. During the return trip, the child asked if he could drive the vehicle. The police investigation revealed the boy had helped steer the vehicle in the driveway on other occasions, while seated in the grandmother's lap. On this occasion, the grandmother gave permission to the child to operate the vehicle seated alone in the driver's seat. The grandmother stopped the vehicle at the entrance to the driveway and exchanged positions with the child. The driver's seat was adjusted in a mid-to-forward track position to allow the child to reach the controls. This positioned the child in close proximity to the driver air bag module. The grandmother was seated in the front center position, close to the child presumably to aid in the vehicle's operation if necessary. Neither occupant of the vehicle was restrained.

Crash

The police investigation revealed the grandmother instructed the child too only depress the brake pedal, as the driveway had a negative grade. However as the vehicle descended into the parking area, the child lost control and the vehicle accelerated forward. Reportedly, the child depressed the accelerator instead of the brake. The front of the Mercury struck the hill side embankment at the end of the driveway. The vehicle's impact speed was an estimated 24 km/h (15 mph).

The force of the impact deployed the vehicle's Supplemental Restraint System (SRS). The driver and front right passenger air bags deployed. The child, seated in close proximity to the driver air bag module, was stuck under the chin by the deploying bag. Contact with the air bag occurred early in the deployment sequence, prior to full expansion. The child's forward position impeded the normal deployment path of the bag. The expansion of the driver air bag, under the chin, hyper-extended the head resulting in a fatal basilar skull (hinge) fracture. The delta V of the impact was estimated to be 13 to 16 km/h (8 to 10 mph).

The vehicle's forward momentum caused it to climb the embankment approximately 2 m (7 ft). Analysis of the on-scene photographs determined the vehicle struck the embankment while under power. This determination was evidenced by an acceleration mark attributed to the right rear tire. The acceleration mark was caused by a loss of traction as the front of the vehicle became elevated against the embankment. The mark was generated coincident to or immediately after SRS deployment. The child would not be able to depress the accelerator at that time because of his upward/rearward kinematic pattern. It was probable that the grandmother attempted to take control of the out-of-control vehicle and also depressed the accelerator instead of the brake. An impression of the rear bumper and rear undercarriage was also observed at the point of impact. Refer to Figure 2. Dirt and debris was thrown up the embankment approximately 4 m (12 ft) by the force of the impact. The vehicle's engine then either stalled or was shut down by the grandmother and the vehicle rolled backward approximately 8 m (26 ft) to final rest. **Figure 3** is an overhead schematic of the crash scene.

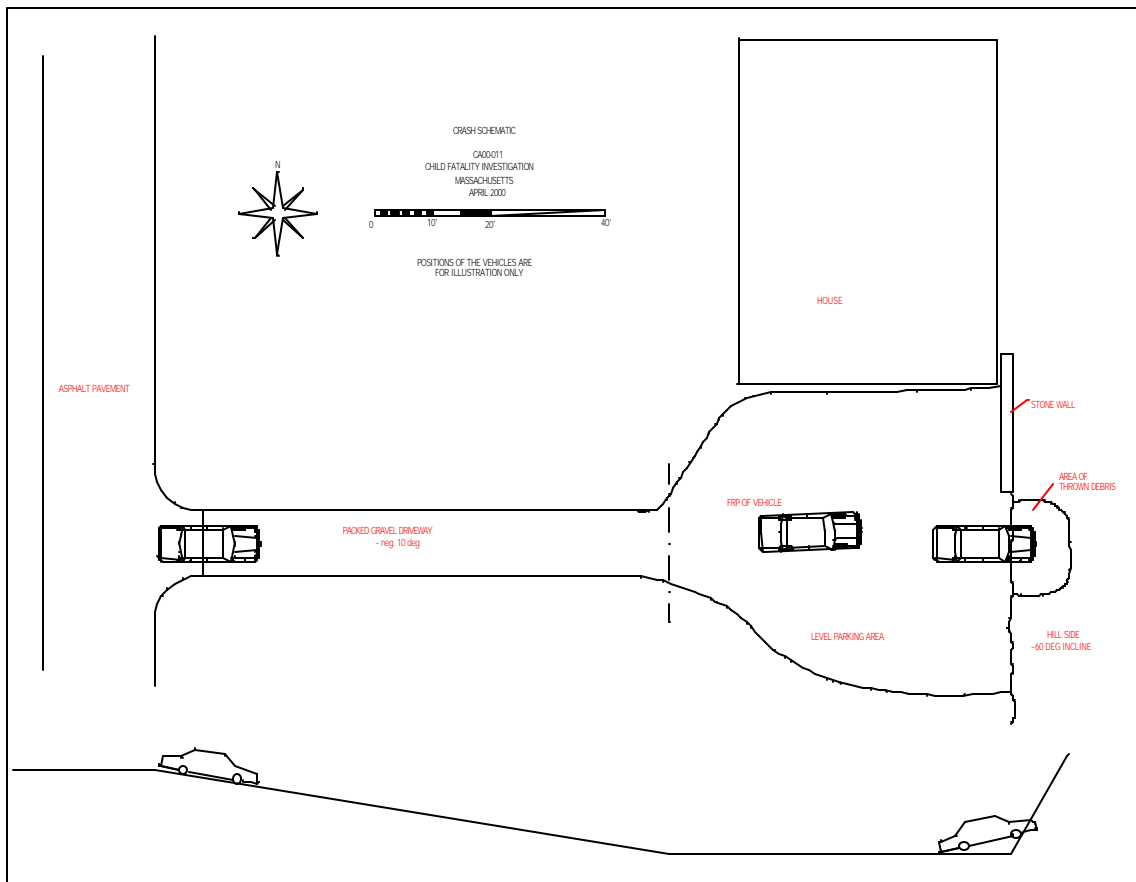


Figure 3: Crash scene schematic.

Post-crash

The grandmother exited the vehicle and yelled to her husband to call 911. Police and ambulance services responded to the scene. The grandmother was observed inside the vehicle holding the child. He was

bleeding profusely from the nose, ears, and mouth. He was not breathing and was unresponsive. EMS personnel reported he had no vital signs. They began resuscitation and transported him to the emergency room of a local hospital. The hospital was located approximately 24 km (15 miles) from the crash site. He was pronounced dead at the hospital 57 minutes post-crash.

1995 MERCURY GRAND MARQUIS

The 1995 Mercury Grand Marquis was identified by a Vehicle Identification Number (VIN): 2MELM75W0SX (production sequence deleted). The vehicle's power train consisted of a 4.6 liter, V-8 engine linked to a four-speed automatic transmission. The 4-door sedan was rear-wheel drive. The standard power-assisted four-wheel disc brakes were equipped with an Anti-lock (ABS) system. The vehicle was equipped with a Supplemental Restraint System that consisted of driver and front right passenger air bags. The date of manufacture was 9/94. The odometer reading at time of inspection was 168,653 km (104,799 miles).

The Mercury was towed from the crash scene by a family member and stored. The interior had been cleaned of the blood evidence and the deployed air bags were packed back into the modules. The vehicle's engine was operational and it had been driven post-crash. The driver's seat had been adjusted to the full rear position. It was not known if the adjustment of the tilt steering wheel had been changed.

Exterior Damage

Figures 4 and 5 are views of the Mercury taken during the on-scene police investigation and SCI inspection, respectively. The Mercury Grand Marquis sustained direct contact damage across the entire 168 cm (66 in) frontal end width. The front bumper system was rotated slightly down and displaced rearward. The residual crush profile measured as follows: C1=2.5 cm (1.0 in), C2=2.5 cm (1.0 in), C3=3.0 cm (1.2 in), C4=2.5 cm (1.0 in), C5=3.0 cm (1.2 in), C6=3.8 cm (1.5 in). The front bumper system was mounted to the uni-body sub-frame by two Energy Absorbing Devices (EAD's). Inspection of the EAD's indicated both had compressed 3.8 cm (1.5 in) as a result of the impact and had returned to their original length through restitution. The force of the impact was managed by the vehicle's front bumper system and structures forward of the radiator support plane. Operation of the hood was restricted by the rearward shift of the front fascia. The center grille was broken and its hollow interior space had been packed full of dirt and debris by the embankment. Sliding contact damage was evident on the front undercarriage's lower air dam and extended 97 cm (38 in) aft of the bumper's leading edge. All doors remained closed during the crash and were operational upon inspection. The windshield was not fractured and the side glazings were intact. The bottom edge of the rear bumper and fuel tank were scratched and abraded from ground contact. This contact occurred as the vehicle climbed the embankment and momentarily came to rest (prior to rolling back to rest). The Collision Deformation Classification (CDC) of the frontal impact was 12-FDEW-01. The Barrier Model was the WINSMASH program calculated a damage based delta V of 18.7 km/h (11.6 mph). This calculated value seems high and represents an upper bound. An estimated delta V, based on SCI experience, of 13 to 16 km/h (8 to 10 mph) is more consistent with the magnitude of the vehicular damage and the dynamics of the crash.



Figure 4: Front view of the Mercury at final rest. Note the volume of dirt accumulated on the vehicle.



Figure 5: Left front view of the Mercury.

Interior Damage

The interior damage to the Mercury was consistent with the deployment of the Supplemental Restraint System and occupant contacts to the interior compartment. There was no interior damage or intrusion related directly to the exterior crash forces. The majority of the blood evidence had been cleaned by a family member prior to the SCI inspection.

The front interior seating system consisted of a leather 60/40 split bench seat. The 6-way power driver's seat was found adjusted to the full rear position. Its adjustment had been changed from its at crash position during the process of moving and cleaning the vehicle. The front right passenger seat was found adjusted to the full rear position. Its track position had not been changed.

The at-crash driver's seat track position was reconstructed using the on-scene photographs and family members' statements. **Figure 6** is a left interior view of the reconstructed seat position. In this position, the track position measured 10.4 cm (4.1 in) rear of full forward.



Figure 6: View of the reconstructed seat position.

The total seat track adjustment measured 25.4 cm (10 in). The horizontal distance from the driver air bag module cover to the seat back measured 41 cm (16 in). The leading edge of the seat cushion was 3.8 cm (1.5 in) rearward of the instrument panel. The horizontal distances from the edge of the seat cushion to the brake pedal and to the accelerator measured 39.5 cm (15.5 in) and 43.2 cm (17.0 in), respectively. Refer to **Figure 7**.

The vehicle was equipped with a tilt steering wheel. It was found to be adjusted to its center position upon inspection. It was not known if this adjustment was changed post-crash. The 12 o'clock sector of the 4-spoke steering wheel rim was deformed forward. The deformation measured 1.3 cm (0.5 in). The deployment of the driver air bag had displaced the cruise control buttons from the control assembly located in the spokes of the rim.



Figure 7: View of the distance from the seat to the foot controls.

Inspection of the steering column indicated it was completely displaced from the shear capsules. The outboard and inboard shear displacement measured 2.8 cm (1.1 in) and 2.0 cm (0.8 in), respectively. The upper rim deformation and shear displacement were attributed to the driver air bag expansion during the impeded air bag deployment. These deformations were not a result of direct occupant contact.

The driver's bolster panel was scuffed from probable contact with the child's lower extremities. The scuff measured 0.8 cm x 0.8 cm (0.3 in x 0.3 in) and was located on the steering column center line. Its elevation above the floor measured 38 cm (15 in).

The expanding air bag lifted the child up during the deployment sequence and into contact with the sun visor. The sun visor and headliner were then abraded by the child's forehead during a rebound contact, **Figure 8**. The abrasion measured approximately 35 cm x 8 cm (14 in x 3 in), length by width, and began 6.4 cm (2.5 in) rearward of the visor's leading edge. The start and end of the contact pattern measured 16.5 cm (6.5 in) and 24.1 cm (9.5 in) inboard of the side rail. Several strands of hair were observed embedded in the abrasion pattern. An abrasion on the crown of the child's forehead was identified during the autopsy resultant to this contact.



Figure 8: View of the abraded sun visor and headliner.

A 1.3 cm x 1.3 cm (0.5 in x 0.5 in) scuff was identified on the center instrument panel trim. The scuff was 52.8 cm (20.8 in) right of the steering column center line and 36.8 cm (14.5 in) above the center tunnel. This scuff resulted from probable contact with the grandmother's right lower extremity. The trim panel was noted to be partially dislodged from the instrument panel (IP) in the on-scene photographs. It was removed from the IP by a family member and found in the back seat at the time of the inspection. The center mirror had been displaced from the windshield by the deploying front right passenger air bag.

Manual Restraints

The front outboard restraints in the 1995 Mercury Grand Marquis consisted of manual 3-point lap and shoulder belts with a sliding latch plate. The inertial locking retractors were located in the base of B-pillars. The front seat belt webbings were stowed in their respective retractors upon inspection. Both latch plates exhibited signs of historical use, consistent with the age of the vehicle. The center lap belt was not accessible. It was found wedged between the front seat cushions. No evidence of manual restraint use was identified during the inspection. The grandmother admitted both occupants were unrestrained during a police interview.

Supplemental Restraint System

The driver air bag module was configured in the typical manner in the center hub of the steering wheel. The H-configuration module cover flaps were constructed of vinyl and were asymmetrical by design. The upper flap measured 20 cm x 13 cm (8 in x 5 in), width by height, and measured 8 mm (0.3 in) in thickness. Blood and body fluid evidence was identified on the lower inboard corner of the flap. No evidence of direct occupant contact was identified on the surface of the flap. The lower flap measured 20 cm x 3.8 cm (8 in x 1.5 in). The lower flap was still rotated open at inspection. It was captured by the 6 o'clock sector of the steering wheel rim during the deployment sequence.

The diameter of the driver air bag measured 61 cm (24 in) in its deflated. The bag was tethered by four 6.4 cm (2.5 in) straps sewn to the face of the bag. It was vented by two 1.3 cm (0.5 in) ports located in the 10/2 o'clock sectors on the back side of the bag. **Figure 9** is a view of the face of the driver air bag. The identification number *103409C* was stamped on the face of the bag. The bag was stained with blood. The heaviest concentrations were located in the 2 and 9 o'clock sectors.

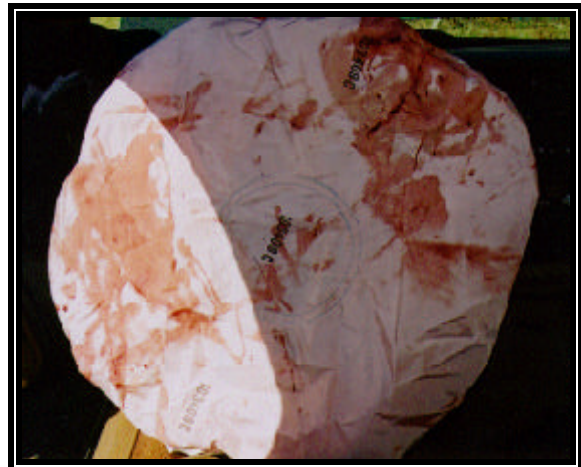


Figure 9: Driver air bag.

A total of eight black vinyl transfers were identified on the face of the bag in the 9 o'clock sector. The transfers were parallel, spaced approximately 2.0 cm (0.8 in) apart and measured 10 cm (4 in) in length. The transfers were oriented vertically. The transfers were the result of frictional contact with the interior surface of the module cover flap during the impeded air bag deployment. Vinyl transfers were also noted on the back side of the bag in its 2 and 9 o'clock sectors. These transfers resulted from frictional contact with the steering wheel rim.

The front right passenger air bag, **Figure 10**, deployed from a mid-mount module, configured in the right aspect of the instrument panel. The module cover flap was a single vinyl flap design, measuring 39.1 cm x 16.3 cm (15.4 in x 6.3 in), width by height. The passenger bag measured 71 cm x 56 cm (28 in x 22 in), width by height, in its deflated state. It was not tethered and was vented by a single 3.8 cm (1.5 in) diameter port located on the inboard side panel. A black scuff was identified on the face of the bag. The scuff measured 8 cm (3 in) in length. It was located 13 cm (5 in) right of the inboard side panel and 10 cm (4 in) below the top of the deflated bag. The scuff mark resulted from air bag contact with the back side of the center mirror. Two areas of spattered blood were also identified of the face of the bag.



Figure 10: Front right passenger air bag.

OCCUPANT DEMOGRAPHICS

	Driver	Front center passenger
<i>Age/Sex:</i>	9 year old/male	71 year old/female
<i>Height:</i>	130 cm (51 in)	estimated 170 cm(67 in)
<i>Weight:</i>	estimated 23 kg (50 lb)	estimated 77 kg (170 lb)
<i>Manual restraint use:</i>	unrestrained	unrestrained
<i>Usage Source:</i>	SCI inspection/passenger statements	SCI inspection/passenger statements
<i>Medical Treatment:</i>	Fatal basilar skull fracture	None

A review of anthropometry tables indicated the child was approximately fiftieth percentile (50 %) for height, given his stated age. Under this assumption, the dimensions of the 9 year old child’s lower extremities indicated he would have been able to reach the foot controls of the Mercury. However, his reach would have been at the outer limits of the controls. Additionally, he would have had to have been seated forward, near the forward edge of the seat cushion. This forward position placed the child’s head and neck in close proximity to the driver air bag module. **Figure 11** is a left interior view of an exemplar vehicle and driver, simulating the at-crash conditions. Note the position of the child forward of the seat back and the extension of his lower extremities in order to reach the foot controls. The exemplar child was 8 years of age with a reported height of 132 cm (52 in).



Figure 11: Left interior view of the exemplar driver seated in exemplar vehicle.

DRIVER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanism
Hinge fracture of the base of the skull with extension onto the left occipital	Severe (150206.4,8)	Deploying driver air bag
Acute subdural hemorrhage, cerebrum, NFS	Severe (140650.4,9)	Deploying driver air bag
Brain swelling, cerebrum, NFS	Serious (140660.3,9)	Deploying driver air bag
Abrasion - under surface chin	Minor (290202.1,8)	Deploying driver air bag
Abrasion - upper left ear	Minor (290202.1.2)	Deploying driver air bag
Abrasion - mid upper anterior neck	Minor (390202.1,5)	Deploying driver air bag

Abrasion - left side neck	Minor (390202.1.2)	Deploying driver air bag
Abrasion - right side neck	Minor (390202.1.1)	Deploying driver air bag
Abrasion - mid-forehead	Minor (290202.1,7)	Left sun visor and headliner

Note: The above injuries were identified in the Commonwealth of Massachusetts Chief Medical Examiner's Postmortem Examination Report.

DRIVER KINEMATICS

The vehicle was stopped at the end of the driveway and the occupants exchanged places. The left front seat was adjusted to a mid-to-forward track position. The 9-year old driver was seated on the forward edge of the driver seat cushion and was unrestrained. Seated in this position, his legs were probably long enough to reach the foot controls but were at the outer limits of their travel. The grandmother was seated in the front center position. She was also unrestrained.

The Mercury was shifted to drive and the vehicle probably coasted down the sloping driveway. As the vehicle approached the base of the slope, reportedly the child was instructed to depress the brake pedal. Due to his unfamiliarity with the driving process, the child apparently depressed the accelerator. As vehicle accelerated forward, the child lost control. During this sequence, the grandmother probably attempted to regain vehicular control from the center position. She probably had her foot in the driver's foot well.

The vehicle struck the embankment under power. The force of the impact caused the vehicle's Supplemental Restraint System to deploy. The vehicle then partially climbed the embankment, evidenced by the displaced soil and debris. As the vehicle's momentum became arrested by the embankment, the rear tires lost traction evidenced by the right rear tire acceleration mark. The rear undercarriage and bumper contacted the ground. The grandmother must have had her foot on the accelerator at this point in time. The child could not have been depressing the accelerator due to the deployment of the air bag system. Contact with the driver air bag would have displaced the child from the accelerator pedal.

The deploying air bag contacted the child under the chin evidenced by the abrasions to the anterior aspect and sides of the neck and under the chin. The forward position of the child impeded the normal deployment path of the air bag evidenced by the scuffs identified on the face and back side of the bag, respectively. The combination of the expansion of the bag and the child's forward kinematic pattern displaced the steering column from the shear capsules.

The expanding air bag hyper-extended the head causing a basilar skull (hinge) fracture. The rapid head acceleration caused by the air bag contact and hyper-extension resulted in cerebral sub-dural hemorrhage and brain swelling. The expansion of the bag lifted the child into contact with the sun visor and headliner

and caused him to rebound rearward. This kinematic pattern was evidenced by an abrasion to the child's mid-forehead. The child then fell back into the driver seat and slumped to the left. His head came to rest in the area of the arm rest on the left door. A large quantity of blood evidence was on the left door, the left aspect of the driver's seat and the floor pan.