TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

Veridian/Calspan
Buffalo, New York 14225

ON-SITE FRONT PASSENGER AIR BAG DEPLOYMENT/ CHILD FATALITY INVESTIGATION

CASE NO. CA99-04

VEHICLE - 1995 HYUNDAI SONATA

LOCATION - NORTH CAROLINA

CRASH DATE - MARCH 1999

Contract No. DTNH22-94-07058

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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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This on-site investigation focused on an intersection collision between a 1995 Hyundai Sonata and a 1988 Dodge Daytona. The front plane of the Hyundai struck the left side plane of the Dodge in a 1/10 o'clock impact configuration. The Hyundai was equipped with a Supplemental Restraint System (SRS) that consisted of driver and right front passenger air bags that deployed as a result of the crash. The unrestrained 6 year old female right front passenger of the Hyundai was fatally injured as a direct result of contact with the deploying right front passenger air bag. The autopsy report revealed the child suffered AIS 5 level brain trauma. The cause of death was listed as cerebral anoxia, cerebral concussion and contusions as a result of blunt force injury to the head.

The Hyundai was eastbound traveling at or within the posted 40 km/h (25 mph) speed limit. Coincident to the Hyundai's approach to the intersection, a 1988 Dodge Daytona was traveling northbound. The driver of the eastbound Hyundai reportedly became distracted when the right front passenger unbuckled and removed her seat belt. The driver indicated to the investigating police officer, that he was aware of the approaching intersection, however his attention was diverted to the unrestrained right front passenger. Upon returning his attention to the roadway, the driver realized he was going to enter the intersection against the traffic signal and northbound traffic. The driver reacted by rapidly applying and locking the brakes. The police investigation identified 4 m (14 ft) of pre-impact skid marks attributed to the Hyundai. The Hyundai skidded into the intersection and the collision occurred. The Dodge was approximately in the center of the intersection at impact. The barrier equivalent speed (delta V) of the Hyundai was approximately 21.4 km/h (13.3 mph).

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ON-SITE FRONT PASSENGER AIR BAG DEPLOYMENT/
CHILD FATALITY INVESTIGATION

CALSPAN CASE NO: CA99-04
VEHICLE: 1995 HYUNDAI SONATA
LOCATION: NORTH CAROLINA
CRASH DATE: MARCH, 1999

BACKGROUND

This on-site investigation focused on an intersection collision between a 1995 Hyundai Sonata and a 1988 Dodge Daytona. The front plane of the Hyundai struck the left side plane of the Dodge in a 1/10 o'clock impact configuration. The Hyundai was equipped with a Supplemental Restraint System (SRS) that consisted of driver and right front passenger air bags that deployed as a result of the crash. The unrestrained 6 year old female right front passenger of the Hyundai was fatally injured as a direct result of contact with the deploying right front passenger air bag. The autopsy report revealed the child suffered AIS 5 level brain trauma. The cause of death was listed as cerebral anoxia, cerebral concussion and contusions as a result of blunt force injury to the head.

The Field Operations Branch of the National Highway Traffic Safety Administration (NHTSA) was informed of the crash on April 3, 1999. NHTSA in-turn assigned an investigation of the crash to the Special Crash Investigation team at Veridian/ Calspan on April 5, 1999. Cooperation with the local police authorities was established and the Hyundai Sonata was placed in the police impound pending SCI inspection. Onsite investigation of the crash occurred April 6, 1999.

SUMMARY

Scene

This two vehicle crash occurred during the nighttime hours of March, 1999. At the time of the crash, it was dark and the crash scene was illuminated by street lights. The weather was not a factor in the crash. The crash occurred at the 4-leg intersection of an east/west 2-lane road and a 2-lane one way (northbound) road located within the city limits. The intersection was controlled by an overhead flashing red traffic light and stop signs for traffic in the east/west direction. The traffic signal was operating properly at the time of the crash. There were no obstructions in the intersection quadrants which would have restricted the drivers' visibility toward the crossing traffic. The speed limit in the area of the intersection was 40 km/h (25 mph). **Figure 1** is an eastbound trajectory view 30 m (100 ft) from the intersection.

Figure 1: Hyundai trajectory view 30 m (100 ft) west of the intersection.

Pre-crash

The 1995 Hyundai Sonata was traveling eastbound, operated by a 40 year old male. He was in the process of transporting the passengers of the Hyundai to a babysitter's house located east of the intersection. The passengers of the vehicle were a 6 year old female and a 4 year old female seated in the right front and right rear of the Hyundai respectively. The 6 year old female in the right front position was not restrained by the Hyundai's available 3-point lap and shoulder belt system. The vehicle was probably traveling at or within the posted 40 km/h (25 mph) speed limit. Coincident to the Hyundai's approach to the intersection, a 1988 Dodge Daytona was traveling northbound on the intersecting street. The Dodge was operated by a 43 year old female. She was restrained by the vehicle's 2-point door mounted automatic shoulder belt and 2-point manual lap belt. The Daytona's right front passenger was a 42 year old male restrained only by the manual lap belt.

Crash

The crash occurred in the following manner. The driver of the eastbound Hyundai reportedly became distracted when the right front passenger unbuckled and removed her seat belt. The driver indicated to the investigating police officer, that he was aware of the approaching intersection, however his attention was diverted to the unrestrained right front passenger. Upon returning his attention to the roadway, the driver realized he was going to enter the intersection against the traffic signal and northbound traffic. The driver reacted by rapidly applying and locking the brakes. The police investigation identified 4 m (14 ft) of pre-impact skid marks attributed to the Hyundai. The Hyundai skidded into the intersection and the collision occurred. The northbound 1988 Dodge Daytona was approximately in the center of the intersection at impact.

The crash occurred with the front plane of the Hyundai striking the left side plane of the Dodge in a 1/10 o'clock impact configuration. The Hyundai impacted the Dodge in the area of the left door's trailing edge and left rear axle. The impact force caused the deployment of the Hyundai's Supplemental Restraint System. The northbound momentum of the Dodge deflected the skidding Hyundai to the northeast. The deflection in the skid marks identified the point of impact. The Hyundai probably came to rest near the end of the skid marks. The vehicle was then driven forward to the final rest location identified by the police investigation, approximately 17 m (58 ft) east the point of impact. The impact caused the Dodge to rotate counterclockwise approximately 225 degrees and slide approximately 10 m (33 ft) to final rest in the northeast quadrant of the intersection. Refer to the crash schematic **Figure 2**. The Hyundai and Dodge were both towed from the crash scene.

Post-crash

The investigating police officer was only 4 to 5 blocks away from the scene at the time of the crash. He estimated he arrived at the scene within one minute of notification. The Hyundai's driver and right rear passenger were out of the vehicle and standing near the rear of the car. The officer spoke to the Hyundai's driver and asked if anyone was injured. He mistakenly understood that the right rear passenger was injured. She was upset and crying. The officer then ran to check on the condition of the occupants of the Dodge. After ascertaining their condition, he then returned to the Hyundai. The driver then indicated the injured occupant was in the right front of the vehicle.

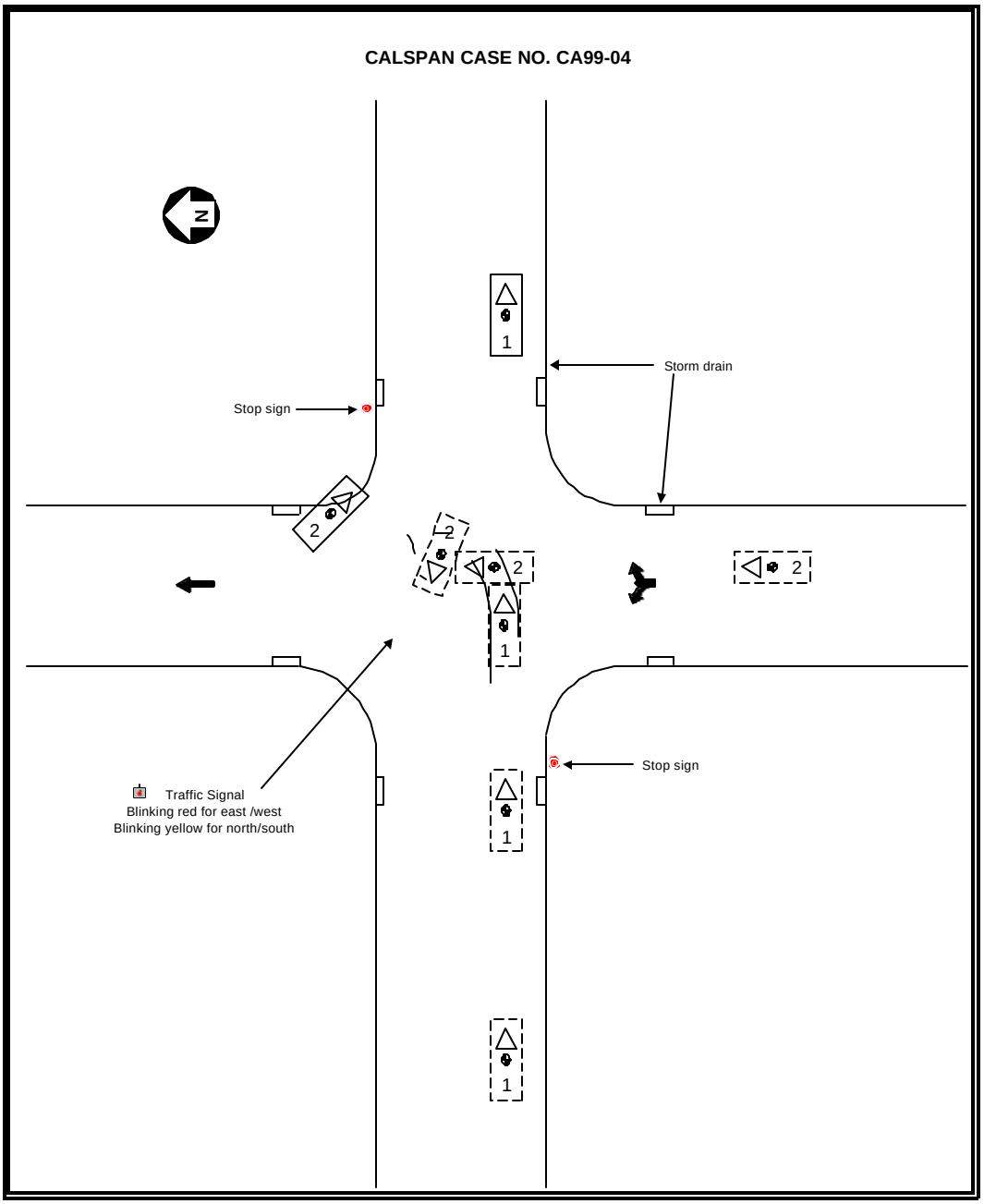

Figure 2: Crash Schematic

The officer ran to the right side of the Hyundai and opened the front door. He noted the air bags had deployed and recalled that the right front air bag appeared fully extended and was laying on the right front passenger seat. He lifted the passenger air bag and saw the 6 year old right front passenger. The child was located in the right front foot well. Her legs were bent at the knees and she was sitting on them (as if she were kneeling). Her shoulders were resting against the leading edge of the right front seat cushion. The child's neck was extended and the back of her head was resting on the seat cushion. She was looking

straight up; her eyes were open. She was not breathing and there was only a faint carotid pulse. The officer removed the child and placed her on the ground just outside the vehicle. The officer tilted the head to establish an airway and heard the child gasp several times. He noted her pupils did not react to his flashlight.

EMS arrived and initiated life supportive measures.. The EMS personnel attempted several times to intubate the child but were unsuccessful. The child was then loaded onto an ambulance and transported to the emergency room of a local private hospital. The hospital was located approximately 1 mile from the crash scene. CPR continued through transport to the hospital. Upon arrival in the emergency room, the child was pulseless and without spontaneous respiration. Resuscitative efforts continued in the hospital for approximately 62 minutes but were ultimately unsuccessful. Diagnostic x-rays of the cervical spine did not indicate fracture or subluxation. An autopsy was ordered and performed the day following the crash. The only external soft tissue injuries noted were several facial abrasions to the left cheek, chin and forehead. There were no skeletal fractures. Internal exam revealed the child suffered multiple brain trauma (AIS 5) as a direct result of the contact with the cover flap and deploying right front passenger air bag. Refer to the injury section, page 9, for the specific injuries incurred.

The Hyundai's driver and right rear passenger were transported, examined and released the evening of the crash. They were not injured. The driver of the Hyundai was impaired at the time of the crash. His Blood Alcohol Content (BAC) was reportedly 0.13. The police officer indicated he was obviously impaired at the scene. The driver was charged with failure to stop at a red light, driving while intoxicated and felony death by motor vehicle. The driver of the Dodge was not injured and the vehicle's right front passenger sustained only a minor head laceration. He too was also treated and released.

AIR BAG VEHICLE

Exterior Damage

The 1995 Hyundai Sonata, 4-door sedan, was identified by the Vehicle Identification Number (VIN): KMHCF24T5SU (production sequence deleted). The vehicle was equipped with a 2.9 liter, V6 engine linked to a 4-speed automatic transmission. The date of manufacture was 12/94. The vehicle's Supplemental Restraint System consisted of dual frontal air bags for the driver and right front passenger. The braking system consisted of standard hydraulic front disc/rear drum brakes. The vehicle was not ABS equipped. The vehicle was purchased used by the mother of the fatally injured child approximately 2 months prior to the crash. The odometer read 188,731 km (117,275 miles) at inspection.

The Hyundai sustained direct contact damage across the vehicle's entire 147 cm (58 in) frontal end width. The impact damage was weighted more heavily to the vehicle's left side due to the lateral momentum of the Dodge Daytona. The front bumper structure was shifted laterally left approximately 8.9 cm (3.5 in) The bumper cover was fractured and dislodged by the impact. The measured crush profile at the bumper

elevation was as follows: C1=14.7 cm (5.8 in), C2=12.7 cm (5.0 in), C3=12.7 cm (5.0 in), C4=13.5 cm (5.3 in), C5=15.2 cm (6.0 in), C6=4.6 cm (1.8 in). The Collision Deformation Classification (CDC) of the damage was 01-FDEW-1. The impact energy was managed primarily by the vehicle's structures forward of the radiator support plane and forward uni-body structure. The hood buckled and folded in the typical manner. The left front fender was buckled but did not restrict the operation of the left front door. All doors were operational and all window glazings were in-tact. The wheelbase dimensions were unchanged. The barrier equivalent speed (delta V) calculated by the barrier model of the WINSMASH program was approximately 21.4 km/h (13.3 mph). The longitudinal and lateral components of the delta V were approximately -20.6 km/h (-12.8 mph) and -5.5 km/h (-3.4 mph), respectively. **Figures 3 and 4** are front and left lateral views of the Hyundai Sonata.

Figure 3: Front view of the Hyundai.

Figure 4: Left lateral view of the Hyundai.

VEHICLE 2

Exterior Damage

The 1988 Dodge Daytona, 2-door hatchback, was identified by the Vehicle Identification Number (VIN): 1B3CA44K6JG (production sequence deleted). The vehicle was equipped with a 2.5 liter, I4 engine linked to a 4-speed automatic transmission. The odometer read 270,922 km (167,348 miles) at inspection. The Dodge sustained 165 cm (65 in) of direct contact damage to the left side of the vehicle. The direct damage began 125.7 cm (49.5 in) forward and ended 39.4 cm (15.5 in) aft of the left rear axle. The maximum lateral deformation at the mid-door elevation measured approximately 7 cm (3 in). Maximum deformation at the lower sill measured 3.5 cm (1.5 in). The left rear axle was directly involved in the impact and was bent from the force of the crash. **Figure 5** is a left side view of the vehicle. The barrier equivalent speed (delta V) calculated by the WINSMASH model was approximately 14 km/h (9 mph).

Figure 5: Left rear view of the Dodge.

AIR BAG VEHICLE

Interior Configuration and Damage

The interior damage to the Hyundai was resultant to the deployment of the vehicle's Supplemental Restraint System and occupant contacts resultant to the crash. There was no interior damage or intrusion related to the exterior forces of the crash.

The steering assembly was configured with a 4-spoke, tilt steering wheel. The wheel was adjusted to the full up position. There was no steering wheel rim deformation. Inspection of the steering column's shear plate indicated there was no displacement of the column. Inspection of the driver knee bolster did not exhibit any evidence of occupant contact. The front seats of the Hyundai were cloth covered, reclining bucket seats. The driver seat was adjusted to a mid-track position and measured 12.2 cm (4.8 in) forward of the rearmost position. The total seat track travel was 23 cm (9 in). The seat back was reclined approximately 34 degrees aft of vertical.

The right front passenger seat was adjusted to the rearmost position at inspection. The seat back was reclined 38 degrees aft of vertical. The reclined seat back was in close proximity to the right rear seat. Considering the right rear position was occupied at the time of the crash, the seat track position probably had been altered from its at crash position. The family of the deceased had access to the vehicle and reportedly removed their personnel belongings. Additionally, several televison news crews had inspected and filmed the vehicle prior to SCI inspection. The seat track was probably adjusted to a mid-track position at the time of the crash consistent with the passenger's stature.

The only possible right front interior contact identified was a possible scuff on the right front knee bolster/glove box door. It was located on the center aspect of the bolster and measured approximately 2 cm (1 in). This minor contact would have been non-injury producing. It was probable this scuff could also have developed from contact during passenger ingress/egress.

Contact evidence was identified on the right aspect of the windshield resultant to the altered deployment path of the air bag. The contact area consisted of two zones. The upper region measured approximately 41 cm x 23 cm (16 in x 9 in) width by height and was associated to direct contact from the air bag. Air bag fabric transfers to the laminate were identified throughout the region. The lower region measured 33 cm x 15 cm (13 in x 6 in) and resulted from contact with the module cover flap. Vinyl transfers were identified in the throughout the lower region. Refer to **Figure 6**.

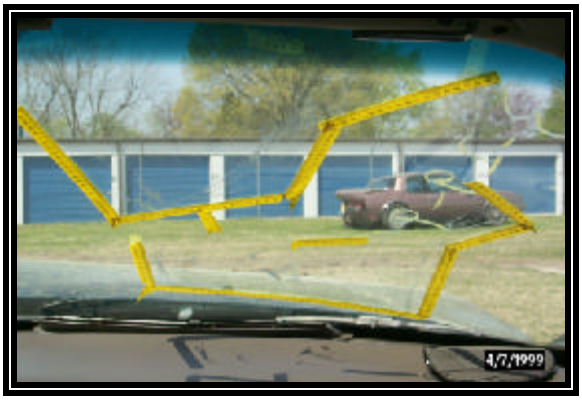

Figure 6: Air bag transfers to the windshield.

An area of the headliner directly above the right front passenger appeared to be slightly abraded. The area

measured 7 cm x 23 cm (3 in x 9 in), width by length, and began 23 cm (9 in) rearward of the header. The fabric was "brushed" longitudinally rearward. This area was probably contacted by the right front passenger's hand/forearm during the rebound phase of the collision.

Manual Restraint System

The manual front restraint system in the 1995 Hyundai Sonata consisted of a 3-point lap and shoulder belt. The belt webbing was a continuous loop and spooled from a dual mode locking retractor located in the base of the B-pillar. The upper anchorages (D-ring) were adjustable.

The left front and right front D-rings were positioned 2 cm (1 in) above and 7 cm (3 in) above the lowest adjustment, respectively. Both front latch plates had evidence of historical usage and the edges of the webbings were dirty and slightly frayed. The outboard restraints in the rear seat were also 3-point continuous loop lap and shoulder belts. These belts also revealed evidence of historical use. There was a lap belt in the center seat position.

The police investigation did not determine belt usage for the driver or right rear passenger. The driver stated to the officer that they were restrained at the time of the crash. The right front passenger was determined to be unrestrained. This determination was based on her final rest position (foot well) and the stowed condition of the belt. The driver stated that the right front passenger had taken off the belt prior to the crash and was the reason for his distraction. In an interview, the child's mother indicated that she normally placed the children in seat belts, however, the fatally injured child had a habit of removing her belt. All evidence identified during the SCI inspection indicated the right front passenger was unrestrained at the time of the crash.

The driver and right rear passenger probably were restrained at the time of the crash. No direct evidence was identified on the respective belt webbings, however given the low magnitude of the crash severity transfers would not be expected. The driver did not contact the bolster nor interact significantly with the driver air bag. He was not injured in the crash. Similarly, the right rear passenger was not injured. The use of the manual restraint probably mitigated her contact with the vehicle's interior.

Supplemental Restraint System

The Hyundai Sonata was equipped with a Supplemental Restraint System (SRS) that consisted of driver and right front passenger air bags that deployed as a result of the crash. The SRS was a single point system with air bag control module located within the occupant compartment. The driver air bag module was configured in the typical manner in the center hub of the steering wheel. The symmetrical H configuration cover flaps measured 19.8 cm by 6.4 cm (7.8 in by 2.5 in), width by height. There was no contact evidence on the surfaces of the cover flaps. The driver air bag measured 66 cm (26 in) in its deflated state and was tethered by two 13 cm (5 in) wide straps. The bag was vented by two 4.6 cm (1.8 in) vent ports located in 10/2 o'clock sectors on the back side of the bag. There was no contact evidence identified on the face of the bag. The following nomenclature was fixed to a bar code label in the 12 o'clock sector on the back side of the bag:

PE5080300
TBY419210117

The right front passenger air bag was a mid-mount design configured in the typical manner in the right aspect of the instrument panel. The module cover flap was vinyl, approximately 1 cm (3/8 in) in thickness, and measured 34.3 cm x 20 cm (13.5 in x 8 in), width by height respectively. **Figure 7** is a close-up view of contact evidence identified on the cover flap. The lower corners of the flap and right aspect of the leading edge were slightly abraded from windshield contact. Located on the left aspect of the flap's leading edge was a 5 cm (2 in) area of polished vinyl. A 2.0 cm (0.8 in) gouge was identified on the leading edge of the flap, immediately to the right of the polished area. Reportedly, the right front passenger's hair was up in multiple pigtails fastened by berrettes. Pieces of a fractured barrette were found on the top of the instrument panel, forward of the module at the base of the windshield. The polished area and gouge probably resulted from contact with the face/head of the right front occupant.

Figure 7: Close-up; view of the contact evidence on the cover flap.

Figure 8: Abraded and scuffed cover flap and Tyvek wrap.

Inspection of the interior surface of the cover flap revealed the surface was scuffed and abraded during the deployment sequence, **Figure 8**. These scuffs and abrasions were caused by the impeded deployment, resultant to the forward position of the right front passenger. Her body position impeded the normal opening of the cover flap and inflation of the air bag. This resulted in frictional heating between the interior surface of the cover flap, protective wrap and air bag. The heating of the vinyl surfaces resulted in the vinyl transfers to the protective wrap and air bag.

The face of the right front passenger air bag measured 51 cm x 56 cm (20 in x 22 in), width by height, and extended 53 cm (21 in) from the module, in its deflated state. The air bag was tethered by a single 15 cm (6 in) wide strap sewn to the upper aspect of the air bag's face. The bag vented internally back through the module. Inspection of the right front passenger air bag identified contact evidence distributed primarily over the inboard and bottom surfaces of the fabric, **Figure 9**. This evidence was associated directly with the altered deployment of the air bag. On the center

Figure 9: Vinyl scuffs to the lower and inboard surfaces of the right front PAB.

aspect of the bag's top surface was a 18 cm (7 in) black vinyl transfer. This vinyl transfer was caused by contact with the interior surface of the cover flap. The only contact evidence on the face of the bag was a 7 cm x 13 cm (3 in x 5 in) transfer localized on the inboard seam of the air bag's face. This transfer continued onto the inboard surface of the air bag and measured 15 cm x 20 cm (6 in x 8 in). These transfers were linked to contact with the windshield. Vinyl transfers were dispersed over a large area on the left aspect of the air bag's bottom surface. The area measured approximately 20 cm x 25 cm (8 in x 10 in), width by length. The vinyl transfers were patterned and linked to contact with the interior surface of the module cover flap.

RIGHT FRONT PASSENGER DEMOGRAPHICS

Age/Sex:	6 year old female
Height/Weight:	119 cm (47 in)/22 kg (48 lb)
Restraint Usage:	unrestrained
Usage Source:	inspection
Medical Transport:	ambulance to local private hospital

RIGHT FRONT PASSENGER INJURIES

Injury	Severity (AIS 90)	Injury Mechanism
Diffuse sub-dural hemorrhage (bilaterally), approx. 15 cc	Critical (140654.5,3)	Cover flap and deploying right front passenger air bag
Petechial hemorrhages in subcortical areas bilaterally as well as in area of basal ganglia on left and lesser extent right	Critical (140646.5,3)	Cover flap and deploying right front passenger air bag
Tentorial herniation	Critical (140202.5,8)	Cover flap and deploying right front passenger air bag
Sanguineous fluid in ventricles bilaterally - intra-ventricular hemorrhage	Severe (140678.4,1) Severe (140678.4,2)	Cover flap and deploying right front passenger air bag
Diffuse sub-arachnoid hemorrhage involving left & right parietal lobes, anterior occipital lobe and left temporal lobe	Serious (140684.3,1) Serious (140684.3,2)	Cover flap and deploying right front passenger air bag
Sub-galeal hemorrhage - over vertex, 4 x 8 cm (1.5 x 3 in)	Minor (190402.1,5)	Cover flap and deploying right front passenger air bag

6x5 cm abrasion left cheek	Minor (290202.1,2)	Cover flap and deploying right front passenger air bag
2x1 cm abrasion forehead - left side	Minor (290202.1,7)	Deploying right front passenger air bag
1 cm dia. abrasion left side of chin	Minor (290202.1,8)	Deploying right front passenger air bag
Small abrasion superior to and lateral to left eye	Minor (290202.1,7)	Deploying right front passenger air bag

RIGHT FRONT PASSENGER KINEMATICS

The 6 year old, fatally injured, female was the unrestrained right front passenger of the Hyundai. Prior to the crash, she reportedly removed her seat belt and was the cause of the driver's distraction. She was seated in a presumed mid-track position and may have moved to a kneeling posture. Immediately prior to entering the intersection, the driver applied and locked the vehicle's brakes evidenced by the pre-impact skid marks. The unrestrained child initiated a forward trajectory in response to the vehicle's braking and became positioned in-close proximity to the front passenger air bag module cover flap. If the passenger had been sitting on her knees, she would have toppled forward. At impact, the vehicle's SRS deployed and the child responded to the 1 o'clock direction of the impact force by moving further forward.

The left aspect of the facial abrasions indicated the child's face was turned to the right. She may have been guarding with her upper extremities. At deployment, the child was positioned in front of the module cover flap and impeded the initial rotation of the cover flap. Pressure and heat built-up within the module evidenced by the frictional scuffs, abrasions and vinyl transfers. The cover flap probably contacted the child in the upper chest and/or face evidenced by the polished surface and small gouge in the cover flap. Head contact with the cover flap and/or expanding air bag imparted a rapid acceleration to the skull resulting in multiple brain hemorrhages and trauma (AIS 5). The forward kinematic pattern of the child altered the deployment path of the air bag up into the windshield. The expanding air bag contacted and abraded the face and probably lifted the child off the seat. As the child rebounded her upper extremities probably contacted the headliner evidenced by the longitudinal bushing of the fabric. The child then fell into the right front foot well where she was found by the investigating police officer.