TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Veridian Engineering
Buffalo, NY 14225

VERIDIAN REMOTE REDESIGNED AIR BAG RELATED CHILD PASSENGER SERIOUS INJURY INVESTIGATION SCI TECHNICAL SUMMARY REPORT

NASS/SCI COMBO CASE NO. 00-12-133J

VEHICLE - 1998 HYUNDAI ELANTRA

LOCATION - STATE OF MICHIGAN

CRASH DATE - AUGUST 2000

Contract No. DTNH22-94-D-07058

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 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 are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

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

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16. *Abstract* This remote investigation focused on a two vehicle intersection-type crash that involved a 1998 Hyundai Elantra that was equipped with redesigned frontal air bags for the driver and front right passenger positions. The left front side area of the Elantra was struck by the front of a straight truck. The impact was sufficient to deploy the redesigned frontal air bag system in the Elantra. The Elantra was occupied by a 32-year-old female driver, a 5-year-old front right child passenger, a 9-year-old passenger and 13-year-old passenger that were seated in the rear seat. All occupants of the Elantra were unrestrained. At impact, the redesigned frontal air bag system deployed and the occupants initiated forward and lateral trajectories. The driver sustained multiple upper extremity soft-tissue injuries. The unrestrained front right child passenger was struck in the face by the deploying redesigned front right passenger's air bag, which resulted multiple soft-tissue facial injuries. He was accelerated rearward and struck his head on the interior surface of the right front door. He sustained a closed head injury with a brief loss of consciousness. The 9-year-old sustained minor soft tissue injuries. The 13-year-old was uninjured. The driver, 5-year-old passenger, and 9-year-old passenger were transported by ambulance to a regional trauma center. The 5-year-old front right passenger was admitted for treatment. The remaining occupants were treated and released. The 13-year-old passenger was not medically treated.			
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BACKGROUND

Figure 1. 1998 Hyundai Elantra

This remote investigation focused on a two vehicle intersection-type crash that involved a 1998 Hyundai Elantra **(Figure 1)** that was equipped with redesigned frontal air bags for the driver and front right passenger positions. The left front side area of the Elantra was struck by the front of a straight truck. The impact was sufficient to deploy the redesigned frontal air bag system in the Elantra. The Elantra was occupied by a 32-year-old female driver, a 5-year-old front right child passenger, a 9-year-old passenger and 13-year-old passenger that were seated in the rear seat. All occupants of the Elantra were unrestrained. At impact, the redesigned frontal air bag system deployed and the occupants initiated forward and lateral trajectories. The driver sustained multiple upper extremity soft-tissue injuries. The unrestrained front right child passenger was struck in the face by the deploying redesigned front right passenger's air bag, which resulted multiple soft-tissue facial injuries. He was accelerated rearward and struck his head on the interior surface of the right front door. He sustained a closed head injury with a brief loss of consciousness. The 9-year-old sustained minor soft tissue injuries. The 13-year-old was uninjured. The driver, 5-year-old passenger, and 9-year-old passenger were transported by ambulance to a regional trauma center. The 5-year-old front right passenger was admitted for treatment. The remaining occupants were treated and released. The 13-year-old passenger was not medically treated.

This crash was selected for investigation by the National Automotive Sampling System (NASS) as CDS case number 00–12-133J. The crash occurred in August 2000. Initial notification of this crash was made to the Veridian Special Crash Investigations team following a NASS CDS case review. The NASS PSU performed the vehicle inspection and scene inspection. The National Highway Transportation Safety Administration (NHTSA) assigned a case review and report preparation to the Veridian Special Crash Investigation (SCI) team on November 3, 2000.

SUMMARY

Crash Site

The crash occurred during daylight hours at the junction of an east/west arterial roadway and a private driveway to a service station. At the time of the crash, it was clear and the asphalt roadway surface was dry. The east/west roadway consisted of two straight and level travel lanes in each direction that were separated by a center turn lane. The concrete driveway was located on the north side of the arterial roadway. There was no traffic control present, however, a three-phase traffic signal was noted west of the junction. The posted speed limit for the east/west roadway was 72 km/h (45 mph). The east/west roadway was bordered by concrete curbs and lawn areas. The roadside environment consisted of commercial properties.

Pre-Crash

The 32-year-old female driver of the Hyundai Elantra was operating the vehicle southbound on the concrete driveway exiting the service station **(Figure 2)**. An uninvolved vehicle had stopped in the outboard westbound lane and that driver signaled to the driver of the Elantra that it was clear to proceed into the roadway. The Elantra's driver proceeded into the roadway and initiated the left turn, but did not detect the westbound heavy truck approaching on the inboard lane **(Figure 3)**. The driver of the truck detected the Elantra turning across its path and applied the brakes in full lockup in an attempt to avoid the collision. The truck skidded longitudinally and stayed in its original travel lane. Skid marks front the front tires of the truck were documented by the NASS researcher. The left front measured 19.2 m (63.0') in length and the right front measured 13.0 m (42.7') in length.

Figure 2. Southbound approach for the Elantra

Figure 3. Westbound approach for the heavy truck

Crash

As the Elantra traveled across the westbound travel lanes, it was struck on the left front side area by the heavy truck. The bumper of the truck contacted the left front fender and overrode the left front bumper corner. The impact resulted in moderate damage to the Elantra and minor damage to the truck. The resultant direction of force was in the 10 o'clock sector for the Elantra and in the 12 o'clock sector for the heavy truck. The damage algorithm of the WinSMASH program computed a total barrier equivalent speed of 23.0 km/h (14.3 mph) for the Elantra. The longitudinal and latitudinal aspects were -11.5 km/h (7.1 mph) and 19.9 km/h (12.4 mph), respectively. The Elantra rotated clockwise (CW) approximately 130 degrees and came to rest facing west in the inboard westbound lane. The truck came to rest facing west in the inboard westbound lane.

Post-Crash

The driver and rear seat child passengers of the Elantra exited the vehicle under their own power. The unconscious 5-year-old front right passenger was removed from the vehicle by the driver. The driver, 5-year-old, and 9-year-old were transported by ambulance to a regional trauma center. The driver and 9-year-old were treated and released. The 5-year-old front right passenger was admitted for his injuries and remained hospitalized for four days. The driver of the heavy truck was not injured and did not receive any medical treatment. The Elantra was towed due to damage and the heavy truck was driven from the scene.

VEHICLE DATA - 1998 Hyundai Elantra

The 1998 Hyundai Elantra was identified by the Vehicle Identification Number (VIN): KMHJF24M4WU (production sequence omitted). The vehicle was a front wheel drive, four-door sedan and was equipped with a 1.8 liter, 4-cylinder engine, manual transmission, and a tilt steering column. The odometer read 62,410 km (38,781 miles) at the time of the NASS vehicle inspection. The seating was configured with front reclining bucket seats with adjustable head restraints and a rear bench seat with integral head restraints for the outboard positions. Both front seating positions were equipped with 3-point manual lap and shoulder belts. The rear outboard seating positions were equipped with 3-point manual lap and shoulder belts and the center position equipped with a lap belt.

VEHICLE DAMAGE

Exterior Damage - *1998 Hyundai Elantra*

The 1998 Hyundai Elantra sustained moderate damage as a result of the impact with the heavy truck. The direct contact damage began at the front left bumper corner and extended rearward 127 cm (50") along the left side of the vehicle **(Figures 4 and 5)**. The vertical location of the damage was approximately 45 cm (18") above the ground. The combined direct and induced damage also began at the front left bumper corner and measured 131 cm (52") rearward along the left side. The maximum crush was located between C4 and C5 and measured 41 cm (16"). The left front fender had been crushed laterally to the right and separated from the front left bumper fascia. The hood was displaced upward and laterally to the right and had buckled rearward at the designated fold points. The top aspect of the left front wheel was displaced to the right and was deflated. Abrasions from the front bumper of the truck were noted on the left front corner of the hood, the left front aspect of the fender, and the left front bumper corner. The Collision Deformation Classification for this impact with the truck was 10-LFEW-3. Six crush measurements were taken by the NASS researcher at the mid-door level and were as follows: C1 = 1 cm (.5"), C2 = 11 cm (4"), C3 = 28 cm (11"), C4 = 37 cm (15"), C5 = 14 cm (6"), C6 = 17 cm (7").

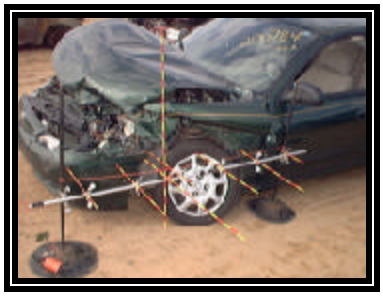

Figure 4. Left front side damage to the Elantra

Figure 5. Longitudinal view of damage

Interior Damage - *1998 Hyundai Elantra*

Interior damage was minor and was attributed to occupant contact **(Figure 6)**. There was no passenger compartment integrity loss. The windshield glazing was cracked from impact forces and the front right passenger's air bag cover flap. The left front door glazing disintegrated from impact forces. There were no measured intrusions. There was no deformation of the steering wheel rim and no identifiable contact to the knee bolster. The left front interior door surface was deformed from occupant contact. Both front seat backs were deformed forward toward the outboard sides from contact by the rear seat occupants.

Figure 6. Interior view of the Hyundai Elantra

Exterior Damage - *1999 International Heavy Truck*

The 1999 International heavy truck was a straight truck with a medium-heavy cube **(Figure 7)**. It sustained minor damage as a result of the impact with the Hyundai Elantra. The direct contact damage was concentrated at the center of the front bumper. The direct and induced damage involved the entire frontal width of the truck. The center area of the bumper was crushed rearward approximately 5 cm (2"). The rear aspect of the left front fender was displaced. The bumper height above the ground was 45 cm (18").

Figure 7. Frontal damage to the heavy truck

REDESIGNED AIR BAG SYSTEM - 1998 Hyundai Elantra

The 1998 Hyundai Elantra was equipped with redesigned air bags for the driver and front right passenger positions which deployed as a result of the impact with the heavy truck. The driver's air bag was housed in the center of the steering wheel with asymmetrical H-configuration module cover flaps. The NASS researcher measured the top cover flap as 16 cm (6") in width and 4 cm (2") in height. The bottom flap measured 16 cm (6") in width and 7 cm (3") in height. The driver's air bag measured 62 cm (24") in diameter in its deflated state. The air bag was tethered by two internal straps and vented by 2 ports located at the 10 and 2 o'clock positions. There was no damage noted to the air bag or module cover flaps. Blood spattering was documented on the driver's air bag.

Figure 8. Driver's redesigned air bag

The redesigned front right passenger's air bag deployed from the mid-instrument panel area with a single cover flap design hinged at the top aspect **(Figure 9)**. The cover flap was rectangular in shape and measured 31 cm (12") in width and 18 cm (7") in height. The air bag measured 45 cm (18") in width and 58 cm (23") in height. The air bag was vented by two ports located at the 10 and 2 o'clock positions. There was no damage noted to the air bag or module cover flaps. Blood spattering was documented on the front right passenger's air bag. A piece of chewing gum was found stuck to the rear aspect of the air bag on the lower right corner.

Figure 9. Front right passenger's redesigned air bag

OCCUPANT DEMOGRAPHICS

Driver

Age/Sex:	32-year-old female
Height:	152 cm (60")
Weight:	54 kg (119 lb)
Seat Track Position:	Full forward
Manual Restraint Use:	Unrestrained
Usage Source:	Driver interview, vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Transported by ambulance to a regional trauma center and treated and released

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Multiple left forearm abrasions	Minor (790202.1,2)	Flying glass
Left upper arm contusion	Minor (790402.1,2)	Left side interior surface
Right forearm contusion	Minor (790402.1,1)	Floor mounted transmission lever, including center console
Laceration on dorsal surface of left 5th finger	Minor (790602.1,2)	Flying Glass

*Injury source: Emergency room records, driver interview

Driver Kinematics

The 32-year-old female driver was seated in an upright posture with the seat back slightly reclined and the seat track adjusted to the full forward position. The driver stated that the tilt steering column was fully lowered. She was not restrained by the available 3-point manual lap and shoulder belt. The driver stated that prior to the impact, she had her left hand on the steering wheel and her right hand on the gear shift lever. At impact with the truck, the redesigned frontal air bag system deployed as she initiated a forward and lateral trajectory to the left. She loaded the deployed driver's air bag which mitigated contact with the steering wheel assembly and instrument panel. Her right arm struck the center console in front of the gear shift lever which resulted in a right forearm contusion. She loaded the left interior door panel which resulted in a left upper arm contusion. She also sustained minor left forearm abrasions and a left hand laceration as a result of flying glass from the left front door window. She was redirected laterally due to the post-impact clockwise (CW) rotation. The driver exited the vehicle under her own power. She was transported by ambulance to a regional trauma center where she was treated and released.

Front Right Child Passenger

Age/Sex:	5-year-old male
Height:	107 cm (42")
Weight:	14 kg (31 lb)
Seat Track Position:	Full forward (vehicle inspection)
Manual Restraint Use:	Unrestrained
Usage Source:	Injury data, driver interview, vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Transported by ambulance to a regional trauma center and admitted for treatment

Front Right Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Unconscious less than one hour	Moderate (160202.2,0)	Right side hardware or armrest
Periorbital contusion (NFS)	Minor (297402.1,9)	Redesigned front right passenger's air bag
Forehead laceration	Minor (290602.1,7)	Redesigned front right passenger's air bag
Forehead contusion	Minor (290402.1,7)	Redesigned front right passenger's air bag
3 cm (1") posterior scalp laceration	Minor (190602.1,6)	Right side hardware or armrest
Right facial abrasion	Minor (290202.1,1)	Redesigned front right passenger's air bag
Central nose abrasion	Minor (290202.1,4)	Redesigned front right passenger's air bag
Anterior scalp abrasion	Minor (190202.1,5)	Redesigned front right passenger's air bag
Forehead abrasion	Minor (290202.1,7)	Redesigned front right passenger's air bag
3 cm (1") right eyelid laceration	Minor (297602.1,1)	Redesigned front right passenger's air bag

*Injury source: Emergency room records, Post-ER medical records

Front Right Child Passenger Kinematics

The 5-year-old front right child passenger was seated in an upright posture with the seat back slightly reclined. The NASS researcher documented the front right seat track in the full forward position at the vehicle inspection. However, the driver stated that the seat was in the full rear position prior to the crash. It was unknown if the seat had been moved post-crash. The child was not restrained by the available 3-point manual lap and shoulder belt. At impact, the redesigned frontal air bag system deployed and the child initiated a forward and lateral trajectory. He was struck in the face by the deploying redesigned front right passenger's air bag which caused a periorbital contusion, and a right eyelid laceration. The air bag expanded across his face which resulted in forehead lacerations, contusions, and abrasions, facial

abrasions, and an anterior scalp abrasion. The expansion of the air bag redirected him rearward and the rear aspect of his head struck the interior surface of the right front door. He sustained a 3 cm (1") laceration to the posterior scalp and brief loss of consciousness, reportedly lasting a few minutes. He was redirected to the left from the CW post-impact rotation. The 5-year-old was removed from the vehicle by the driver. He was transported by ambulance to a regional trauma center where he was admitted for treatment. He was hospitalized for four days and released.

A piece of chewing gum was identified on the rear aspect of the air bag on the bottom right corner. It was unknown if the 5-year-old front right passenger was chewing it prior to the crash.

Rear Center Child Passenger

Age/Sex:	9-year-old male
Height:	130 cm (51")
Weight:	36 kg (79 lb)
Seat Track Position:	Fixed
Manual Restraint Use:	Unrestrained
Usage Source:	Driver interview, vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Transported by ambulance to a regional trauma center and treated and released

Rear Center Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Right periorbital contusion	Minor (297402.1,1)	Front left seat back support
Chest contusion (NFS)	Minor (490402.1,9)	Front left seat back support

*Injury source: Emergency room records, driver interview

Rear Center Child Passenger Kinematics

The 9-year-old male rear center child passenger was seated in an upright posture. He was not restrained by the available manual lap belt. At impact he initiated a forward and lateral trajectory and loaded the front left seat back. The loading caused the inboard edge of the seat back to be deformed forward. He struck the right rear aspect of the seat back with his face and sustained a right periorbital contusion. The driver stated that the child also sustained an unspecified chest contusion as a result of the loading to the seat back. The 9-year-old exited the vehicle under his own power. He was transported by ambulance to a regional trauma center where he was treated and released.

Rear Right Child Passenger

Age/Sex:	13-year-old male
Height:	155 cm (61")
Weight:	48 kg (105 lb)
Seat Track Position:	Fixed
Manual Restraint Use:	Unrestrained
Usage Source:	Driver interview, vehicle inspection
Eyewear:	None
Type of Medical Treatment:	Uninjured and not transported to any medical facility

Rear Right Child Passenger Kinematics

The 13-year-old male rear right passenger child was seated in an upright posture. He was not restrained by the available 3-point manual lap and shoulder belt. At impact, he initiated a forward and lateral trajectory. He loaded the left aspect of the front right seat back. The loading caused the inboard edge of the seat back to be deformed forward. He did not sustain injury and was not transported to any medical facility.

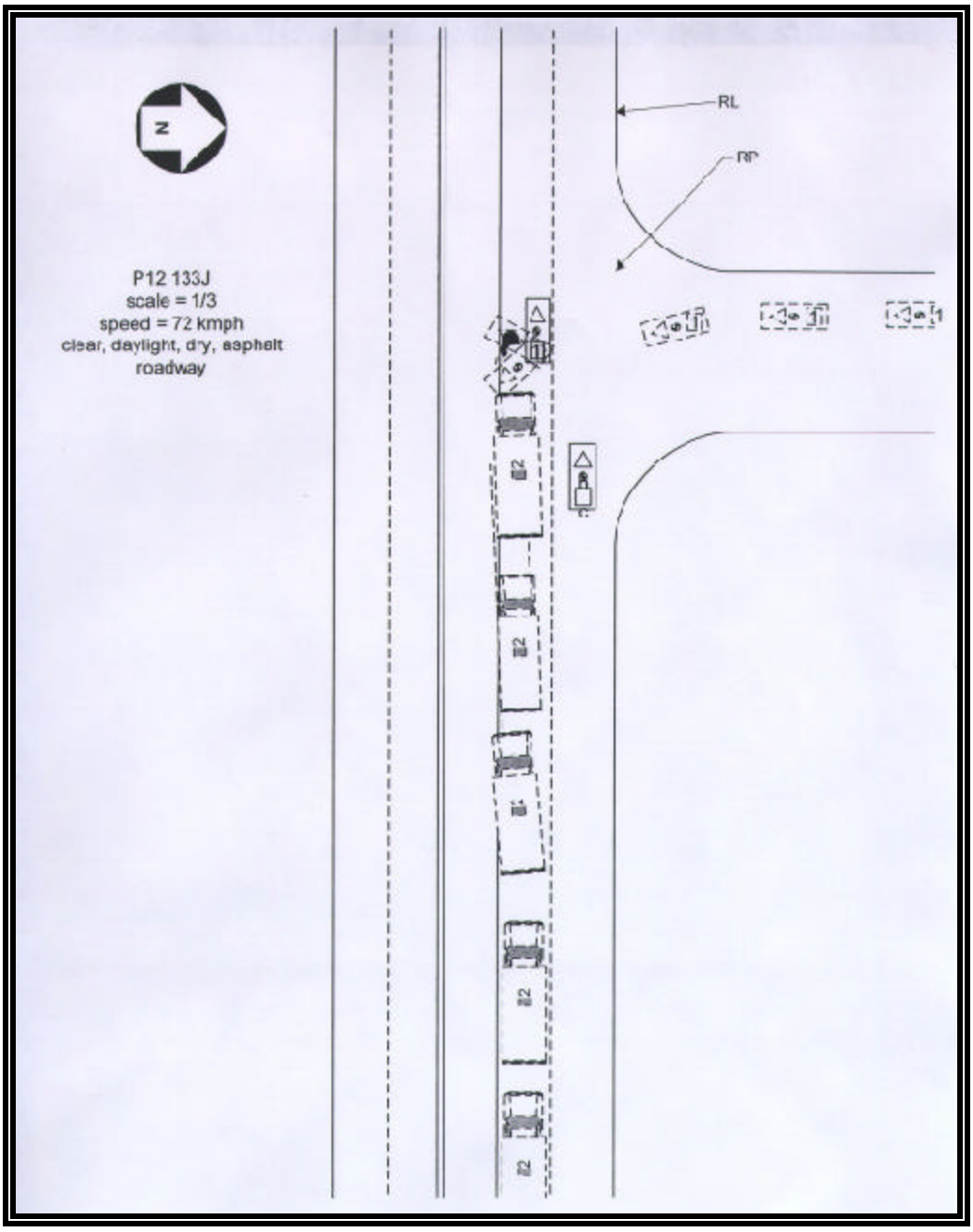

Figure 10. NASS scene schematic