CRASH DATA RESEARCH CENTER

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Buffalo, NY 14225

CALSPAN ON-SITE OFFICE OF DEFECTS INVESTIGATION

AIR BAG NON-DEPLOYMENT CRASH INVESTIGATION

SCI CASE NO.: CA08003

VEHICLE: 2001 HYUNDAI ELANTRA

LOCATION: NEW YORK

CRASH DATE: JANUARY 2008

Contract No. DTNH22-07-C-00043

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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AIR BAG NON-DEPLOYMENT CRASH INVESTIGATION
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BACKGROUND

This on-site investigation focused on the severity of the crash, the issues related to the non-deployed status of the vehicle's frontal air bag system, and the injury severity and cause of death for the 18-year old male driver of the 2001 Hyundai Elantra GLS. The Hyundai was equipped with redesigned frontal air bags, retractor pretensioners, and seat back mounted side impact air bags for the driver and front right passenger positions. The Elantra was involved in a severe head-on crash with a 1990 Toyota pickup truck **(Figure 1)**. The air bags in the Hyundai did not deploy. The driver of the Hyundai was restrained by the manual safety belt system. He loaded the safety belt webbing and the steering assembly with his torso and the instrument panel and knee bolster with his knees and lower legs. As a result of the frontal crash forces and his involvement with the interior components, the driver sustained a fracture of the atlanto-occipital joint, subdural hemorrhage, mesenteric contusions, a pelvic fracture, a mandible fracture, and soft tissue injuries. He expired at the scene of the crash. The driver and two male passengers of the Toyota sustained minor severity injuries and were treated at a local hospital and released.

Figure 1. On-Scene image of the vehicles at final rest.

The investigating police agency provided notification of the crash to the Calspan Special Crash Investigations (SCI) team on Monday, January 28. The notification was immediately forwarded to the Crash Investigation Division and the Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration. Following the review of the notification, ODI requested an on-site investigation. The Hyundai was impounded by the investigating police agency and an inspection date of Wednesday January 30 was coordinated with the officer to meet the requirements of his schedule. The investigation of the Hyundai involved the documentation of the exterior crush profile, repowering the vehicle's electrical system to test the instrument panel air bag status warning light, the download of stored codes using a SnapOn Solus scan tool, the documentation of the vehicle's interior, and the removal of the Air Bag Control Module (ACM) and the Engine Control Module (ECM) at the request of ODI.

SUMMARY

Crash Site

This crash occurred on a rural two-lane road during daylight hours. At the time of the crash, the asphalt road surface was dry and the skies were cloudy. In the vicinity of the crash site, the roadway was straight with the east and west travel lanes having negative grades that transitioned to a sag area **(Figure 2)**. The travel lanes were 3.7 m (12') in width and were bordered by 3 m (10') asphalt shoulders with cable guardrail systems paralleling the outboard edge of the shoulders. The posted speed limit was 89 km/h (55 mph).

Figure 2. Eastbound view of the crash scene.

Vehicle Data

2001 Hyundai Elantra GLS

The 2001 Hyundai Elantra GLS was a four-door sedan that was manufactured on February 5, 2001 and identified by Vehicle Identification Number (VIN): KMHDN45D41U (production number deleted). The vehicle was originally purchased as a new vehicle by the driver's mother on August 30, 2001. She maintained possession of the vehicle and transferred ownership to the driver on July 11, 2007. The Hyundai had no reported service history or previous crashes. The odometer reading at the time of title transfer was 158,516 km (98,500 miles). The 19-year old male driver purchased four new tires on November 1, 2007. The odometer reading at this service interval was 171,828 km (106,772 miles). The driver used the vehicle for transportation to work, college, and recreational activities. The odometer reading at the time of the crash was unknown.

The Hyundai was equipped with a 2.0 liter transverse mounted four-cylinder gasoline engine linked to a four-speed automatic transmission with a console mounted shifter. The service brakes were power-assisted front disc and rear drum without antilock. The Elantra was equipped with a factory sunroof that was closed at the time of the crash. All four door windows were closed. The door glazing was OEM AS2. The vehicle manufacturer recommended tire sizes were 185/65R15 or 195/60R15 with a cold tire pressure of 206 kPa (30 PSI). The tires purchased in November were Sigma Regent Touring HR, size 195/60R15. The tires were mounted on OEM steel wheels concealed by plastic hubcaps. The tire data at the time of the SCI inspection was as follows:

Position	Measured Tire Pressure	Measured Tread Depth	Damage
Left Front	228 kPa (33 PSI)	7 mm (9/32")	None
Left Rear	241 kPa (35 PSI)	7 mm (9/32")	None
Right Front	Tire Flat	6 mm (8/32")	Inside sidewall cut
Right Rear	165 kPa (24 PSI)	6 mm (8/32")	None

The interior of the Hyundai Elantra was configured as a five-passenger sedan with front bucket seats and a rear bench seat with split forward folding seat backs. The front seats were equipped with adjustable head restraints and both head restraints were in the full-down positions. At the time of the crash, a collegiate jacket was extended over the rear aspect of the front right seat back and head restraint.

The safety systems consisted of the redesigned frontal air bags, front safety belt retractor pretensioners, front seat back mounted side impact air bags, and manual safety belts for the five seating positions. The driver's air bag was concealed within the module positioned within the hub area of the four-spoke steering wheel rim. The front right air bag was a top mount design with a single cover flap on the top right instrument panel. The side air bags were incorporated into the upper third aspect of the side surfaces of the front seat backs and affixed with sewn-on labels designating SIDE AIR BAG. The front and side impact air bags did not deploy in this crash and the pretensioners did not actuate.

The safety belt systems were continuous loop three-point lap and shoulder belts with sliding latch plates. The driver's system utilized an Emergency Locking Retractor (ELR) while the remaining systems retracted onto switchable ELR/Automatic Locking Retractors. Post-crash, both front retractors remained operational and allowed spool-out and retraction of the belt webbing.

1990 Toyota Pickup Truck

The struck vehicle in this crash was a 1990 Toyota SR-5 extended cab pickup truck with a short cargo box with a wheelbase of 285 cm (112.3"). The Toyota was manufactured in May 1990 and was identified by the following VIN: JT4VN13DXL5 (production number deleted). The vehicle was configured on a four-wheel drive chassis with a 3.0 liter six-cylinder, conventionally mounted gasoline engine linked to a five-speed manual transmission with a floor mounted shifter. The vehicle manufacturer recommended tire size was 225/75R15 with cold tire pressures of 179 kPa (26 PSI) front and 241 kPa (35 PSI) rear. The Toyota was equipped with Steel Belted M&S all-season tires, sized at 235/75R15. The tire data at the time of the SCI inspection is identified in the following table:

Position	Measured Pressure	Measure Tread Depth	Damage
Left Front	207 kPa (30 PSI)	6 mm (8/32")	No damage
Left Rear	207 kPa (30 PSI)	5 mm (6/32")	No damage
Right Front	Tire Flat	6 mm (8/32")	Sidewall cut
Right Rear	207 kPa (30 PSI)	4 mm (5/32")	No damage

The interior of the Toyota was configured with front bucket seats with adjustable head restraints and a forward facing rear bench seat with a forward folding seat back. The front head restraints were adjusted to an upper position. The Toyota was occupied by a 43-year old male driver, and two 14-year old males seated in the front right and rear right positions. The driver and front right passenger were restrained by the manual safety belt systems while the rear seated passenger was unrestrained.

Crash Sequence

Pre-Crash

The 18-year old male driver of the Hyundai Elantra was a full-time college student and held a full-time, third-shift job. He was returning to his residence following the completion of his assigned work shift and was traveling in a westerly direction on the two-lane road. As he was negotiating the straight road with a down slope, he apparently fell-asleep and allowed the Hyundai to drift left across the centerline, into the eastbound travel lane and onto the south shoulder.

The driver of the Toyota was traveling in an easterly direction and observed the Hyundai encroach into his lane of travel. He applied a right steering input and braked with sufficient force to lock the front wheels of the vehicle. The Toyota skidded in a tracking attitude onto the south (right) shoulder **(Figure 3)**. Although the front tire skid marks were not visible at the time of the SCI inspection, the police documented skid mark lengths of 23.5 m (77') from the left front tire and 26.8 m (88') from the right front tire.

There was no physical evidence at the crash site to support avoidance action by the driver of the Hyundai. The Crash Schematic is included as **Figure 17** of this report.

Figure 3. Trajectory of the Toyota and the pre-crash skid marks.

Figure 4. Trajectory of the Hyundai from pre-crash to impact to final rest.

Crash

The vehicles impacted in an angled head-on configuration on the south shoulder of the roadway **(Figure 4)**. The directions of force were within the 12 o'clock sector for both vehicles with improved force directions of 10 degrees for the Hyundai and -10 degrees for the Toyota. The impact crushed the front right bumper corner of the Hyundai to a depth of 74 cm (29.5") and the upper radiator support to a depth of 89 cm (35"). The damage extended across the full frontal plane of the Hyundai with a crush value of 17 cm (6.6") at the left bumper corner **(Figure 5)**. The front right bumper corner of the Toyota crushed to a maximum depth of 51 cm (20.25"). The damage algorithm of the WINSMASH program computed total delta V's of 69 km/h (43 mph) for the Hyundai and 60 km/h (37 mph) for the Toyota. The specific longitudinal and lateral components were -68 km/h (-42 mph) and -12 km/h (-7 mph) for the Hyundai and -59 km/h (-37 mph) and 10 km/h (6 mph) for the Toyota. The redesigned frontal air bags did not deploy and the retractor pretensioners did not actuate in the Hyundai.

As the vehicle crushed, the Hyundai continued forward and was displaced laterally to its left by the Toyota. Deep gouge marks were present in the asphalt shoulder surface that evidenced the engagement of the vehicles. The left side of the Hyundai engaged the cable guardrail system that prevented the vehicle from departing the shoulder. The three cables snagged the left front fender and door as the right rear door impacted an I-beam post that crushed the door to a depth of 5 cm (2”). At final rest, the cables were tensioned across the front left corner of the vehicle and left side surface **(Figure 6)**. The Toyota was defected rearward of the point of impact and rotated approximately 15 degrees clockwise prior to coming to rest fully engaged against the front of the Hyundai.

Figure 6. Overhead view of the crush to the Hyundai Elantra.

Figure 5. Guardrail engagement of the Hyundai.

Post-Crash

The driver of the Hyundai remained in his position and expired at the scene of the crash. He was restrained; however, at final rest, the latch plate was unbuckled from the inboard mounted buckle and the shoulder belt webbing was loosely retracted and gathered over his left shoulder. It is unknown if the latch plate was unbuckled by a first responder as they assessed the condition of the driver, or by the driver immediately following the impact prior to succumbing to his injuries.

The driver and teenage passengers of the Toyota exited the vehicle unassisted and were transported by ground ambulance to a local hospital where they were treated for their injuries and released. A local tow service removed both vehicles from the scene of the crash. The Hyundai was towed to the police agency where it was impounded for investigation by the police and SCI.

Vehicle Damage

2001 Hyundai Elantra – Exterior

The Hyundai Elantra sustained severe frontal damage from the head-on impact with the Toyota pickup truck. The frontal damage was documented using a frontal reference line that represented the original length of the vehicle. The front reference line was set 450 cm (177.3”) forward of the undamaged back plane of the vehicle.

The direct contact damage extended across the full width of the vehicle and measured 108 cm (42.5) in width along the face of the hood. The bumper fascia was separated by crash damage. The bumper beam and the upper radiator support were crushed rearward

and profiles were documented at these levels. Maximum crush at the bumper beam was 74 cm (29.25") located at the right corner. The upper radiator support was crush rearward 89 cm (35") at the C5 location, 38 cm (15") right of the vehicle centerline. The crush profile at the level of the bumper beam was as follows: C1 = 17 cm (6.6"), C2 = 40 cm (15.9"), C3 = 67 cm (26.25"), C4 = 71 cm (28"), C5 = 72 cm (28.5"), C6 = 74 cm (29.25"). The profile at the upper radiator support was as follows: C1 = 10 cm (3.75"), C2 = 54 cm (21.25"), C3 = 74 cm (29.25"), C4 = 80 cm (31.5"), C5 = 89 cm (35"), C6 = 83 cm (32.6'). The direct contact damage extended onto the upper right A-pillar. The hood latch held during the crash and was released during the SCI inspection. Both hood hinges remained intact. The hood was removed during the inspection to gain access to the engine compartment. The Collision Deformation Classification (CDC) for this event was 12-FDAW-6.

The left side of the Hyundai engaged the cable guardrail as the vehicle continued forward and rotated CW following the impact with Toyota. At final rest, the cables were tensioned across the left front fender of the vehicle. The left rear door sustained 5 cm (2") of crush from contact with an I-beam guardrail post. The direct contact damage on the left side of the Elantra began 37 cm (14.5") forward of the left rear axle and extended 315 cm (124") forward to the corner of the left front fender. The CDC for this event was 10-LYEW-1.

The right wheelbase was reduced in length by 27 cm (10.8") while the left wheelbase was lengthened by 4 cm (1.4"). The left front door was jammed closed by the exterior deformation and was opened and removed by the on-scene fire department to facilitate the extrication of the driver's body. The left rear door remained closed and operational post-crash. The right front door was jammed closed by the exterior crush. The door latch of the right rear door was released at the time of the SCI inspection; however, the door was jammed closed by deformation.

The windshield was cracked full width and height by the deformation. The laminated glass split along the lower third of the left A-pillar and the full length of the right A-pillar. The sunroof was closed and remained intact during the crash. The left rear and backlight glass remained intact during the crash. The driver's door and right side glazing were closed pre-crash and shattered during the event.

2001 Hyundai Elantra – Interior

The interior of the Hyundai sustained damage that was associated with exterior deformation and driver contact. The interior was reduced in size by intrusion of frontal components. The maximum intrusion was 23 cm (9") of rearward displacement of the right mid instrument panel into the front right passenger position. The documented intrusions are listed in the following table:

Occupant Position	Component	Magnitude	Direction
Front left	Seat cushion	8 cm (3”)	Vertical
Front left	Seat back	8 cm (3”), loose	Longitudinal
Front left	Center instrument panel	10 cm (4”)	Longitudinal
Front right	Toe pan	15 cm (6”)	Longitudinal
Front right	Right mid instrument panel	35 cm (9”)	Longitudinal

The driver of the Hyundai was restrained by the manual safety belt system. He loaded the belt webbing as evidenced by frictional transfers on the webbing from the latch plate and D-ring surfaces. His left knee contacted and fractured the left instrument panel and fuse box cover, in addition to the upper aspect of the knee bolster. The contact was located 53-70 cm (21-27.5”) left of the vehicle’s centerline and 19-33 cm (7.5-13”) below the top surface of the instrument panel. The driver’s right knee fractured the bolster panel at its juncture with the mid panel. The vertically oriented fracture pattern compressed the panel inward approximately 4 cm (1.5”).

The driver loaded the lower aspect of the steering wheel rim. His loading force deformed the steering wheel spokes that resulted in 8 cm (3”) of forward displacement of the lower steering wheel rim. A separation of 4 cm (1.5”) was noted between the non-deployed air bag module cover and the steering wheel hub between the lower spokes. The wheel rim was not deformed. The loading of the wheel was transmitted into the energy absorbing steering column, resulting in 6 cm (2.5”) of left shear capsule separation. The top of the soft-edged steering wheel rim was abraded to a flat surface; however, this abrasion did not appear to be crash related. Within the abrasion, was a small puncture that may have resulted from facial contact (tooth) by the driver.

1990 Toyota Pickup Truck

The Toyota sustained moderate frontal damage from the head-on impact event with the Hyundai Elantra. The direct contact damage was distributed across the full width of the front bumper and measured 142 cm (56”) in length along the deformed profile. The bumper corners were projected to the reference line which resulted in a combined induced and direct Field L measurement of 137 cm (54”). Six equidistant crush values were documented along the damage frontal profile and were as follows: C1 = 11 cm (4.25”), C2 = 20 cm (8”), C3 = 36 cm (14.25”), C4 = 36 cm (14.25”), C5 = 39 cm (15.25”), C6 = 51 cm (20.25”). The maximum crush was located at the front right bumper corner. The right wheelbase was reduced in size by 22 cm (8.7”) while the left wheelbase was elongated by 41 cm (1.6”). The CDC for this event was 12-FDEW-3.

The body of the Toyota was heavily rusted. Both lower door skins were rusted from the bottom surface of the door. The doors remained closed during the crash and were opened post-crash. Due to the distortion of the body, the doors would not re-latch. The windshield was cracked and all side glazing remained intact. The sliding rear window was gasket mounted and separated from frame. The tempered glass was not damaged.

Manual Safety Belt Systems
2001 Hyundai Elantra

The Hyundai was equipped with three-point lap and shoulder belts at the five designated seating positions. All belt systems utilized sliding latch plates on continuous loop webbings. The driver's belt webbing retracted onto an Emergency Locking Retractor (ELR) that was equipped with a retractor pretensioner. All other belt systems utilized switchable ELR/Automatic Locking Retractors. Both front belt systems were equipped with adjustable D-rings that were adjusted to the upper positions. The retractor pretensioners did not activate in this crash.

Although the driver's latch plate was unbuckled post-crash, significant loading evidence was present on the belt webbing and hardware to confirm usage at the time of the crash. Frictional abrasions were present on both sides of the latch plate with a matching transfer on the belt webbing. The belt abrasion began 69 cm (27") above the lower outboard anchor point and was 15 cm (6") in length. A small 0.6 cm (0.25") cut was present on the bottom edge of the belt webbing within the frictional abrasion transfer. Body fluid was present on the lap belt webbing from the transfer to the outboard anchor.

Driver loading of the belt system was also present at the D-ring as evidenced by a 10 cm (4") long full-width plastic transfer. The plastic transfer on the webbing had the feel of coarse-grit sandpaper. The transfer was located 118-128 cm (46.5-50.5") above the floor anchor. The full-width of the D-ring was heavily abraded.

Air Bag System/Control Module
2001 Hyundai Elantra

As previously noted, the frontal air bag system in the Hyundai did not deploy. The initial observations by the SCI investigator noted that the negative battery cable was cut post-crash by rescue personnel to remove potential battery power to the vehicle. The battery was located at the front left corner of the engine compartment and the battery case was fractured by the crush. The driver's air bag module protruded rearward from the steering wheel assembly due to the driver loading the lower aspect of the steering wheel rim and deforming the four steering wheel spokes. The clockspring was visible from the top left aspect of the steering column.

The front right air bag was concealed within the right upper instrument panel that intruded rearward. The cover flap was not disturbed from its original position. Both retractor pretensioners appeared to have not actuated during the crash. The left interior B-pillar cover separated from its attachment points exposing the driver's retractor. A yellow wire extended to the retractor that remained fully operational.

In conjunction with the investigating officer and his staff, a plan was created to inspect and analyze the air bag system. The plan included checking all fuses, powering-up the vehicle using a 12-volt jump box connected to the battery cables to check for instrument panel indicator/warning lights and the post-crash status of the air bag indicator light. The police agency had recently purchased a SnapOn Solus Pro Diagnostic Scan Tool. This tool could be utilized to download codes from the vehicle through the Diagnostic Link

Connector (DLC). Lastly, the center console was to be removed to inspect the condition of the Air bag Control Module (ACM) and the multi-pin connector. The outcome of this plan is described below.

A 12-volt power supply was connected to the battery cables. It should be noted that the OEM positive cable connector had been replaced by an aftermarket lead-type connector. The negative cable retained its original connector. This connector was cut; however, both cables remained intact. To better access the battery, the hood was unlatched and removed from the rear mounted hinges. With power supplied to the battery cables, the instrument panel lights and the glove box light illuminated, but not the indicator/warning lights. The brake lights and the center high-mounted brake light illuminated. A 12 volt test light was used to test the continuity of the fuses. All were in place and intact, in proper operating condition. Two interior mounted fuses were labeled Air Bag; a 10 amp and a 15 amp fuse. Both tested "good". The power was removed from the cables and reapplied. On the second attempt, the instrument panel lights did not illuminate while the brake lights illuminated. Again, no warning lights on the instrument cluster.

The SnapOn Solus Pro scan tool was connected to the DLC and the 12 volt power supply was connected to the vehicle's power outlet. The menus were reviewed and the air bag system was tested. Initially, a single code was detected; however, upon review of the tool's output, six codes were stored and labeled as 01/06 – 06/06. The codes and descriptions were as follows:

1.	B1349	DAB Short to Batt	01/01	
2.	B1355	PAB Short to Batt	02/06	
3.	B1620	SRSCM Internal Failure	03/06	**(Figure 7)**
4.	B1364	DBPT Short to Batt (HIST)	04/06	**(Figure 8)**
5.	B1112	Battery Voltage Low (HIST)	05/06	
6.	B1352	PAD Resistance Low (HIST)	06/06	

Another code unrelated to the air bag system was detected.

1. P1723 TCM Control Relay Always On

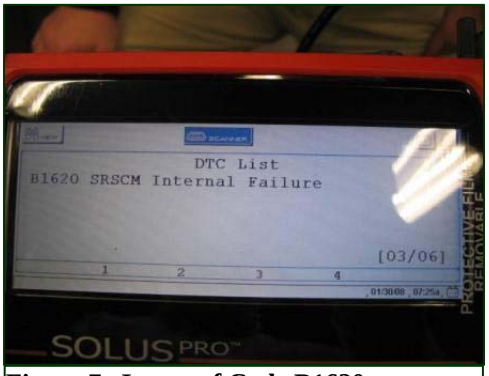

Figure 7. Image of Code B1620.

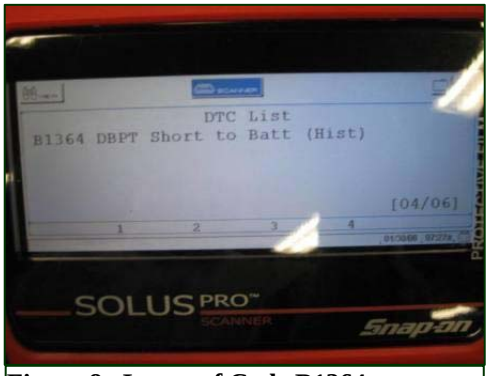

Figure 8. Image of Code B1364.

The center console cover remained intact and was a single molded form consisting of a concealed compartment at the rear aspect with two integrated cup holders located between the compartment and the transmission shifter. The emergency brake lever was located at the mid point of the console cover adjacent to the left side of the cup holders. Two rear screws were removed from the sides of the console and the console was lifted upward and removed.

The boot surrounding the emergency brake lever was contoured to an S-shape. The inboard aspect of this boot had a horizontal flare that was 1.3 cm (0.5") in width. Liquid and objects that spilled from the cup holder area could pass between the console and the emergency brake boot. The shape of the boot and the 1.3 cm (0.5") flare would channel the liquid onto the left aspect of the ACM and the pin connector.

The ACM was fully visible following the removal of the console. The left third aspect of the ACM was stained with a sticky brown substance with hair, coins, and a wax medallion stuck to the top cover **(Figure 9 and 11).** A purple multi-pin connector was fully engaged and secured to the left side of the ACM. This connector was stained with the same substance noted above. The ACM was secured to the center floor with four 10 mm bolts at the corner of the unit. These bolts were tight and were subsequently removed.

Figure 9. ACM and connector as found in vehicle.

Figure 10. Condition of console floor with ACM removed.

The ACM was held in position by the wiring harness. The harness extended from the connector with a yellow wire loom lead extending forward, a second yellow loom lead extending to the left, and a third extending to the right. A decision was made to cut the harness at three locations to remove the ACM from the vehicle. This was accomplished using a long-reach pair of diagonal cutters.

Figure 11. Removed ACM and pin connector.

Figure 12. Back side of the ACM.

With the ACM removed, the floor area under the module appeared to be in good condition with no areas of rust or corrosion **(Figure 10)**. The back side of the ACM was clean and free of corrosion **(Figure 12)**. Numerous objects had fallen between the console and the emergency brake lever and were scattered around this area. None of these objects were positioned between the connector and the ACM.

The ACM with the multi-pin connector in place was examined. The ACM was manufactured by Delphi and was identified by the following nomenclature:

Air Bag ESPS Unit

Delphi	95910 20500
093384969	Ver 4.1
69D4901UUBR	5 10000508

The purple-colored pin connector was removed from the ACM. This was accomplished by rotating a cam lever to disengage the connector and removing the connector from the ACM **(Figure 13)**. Minimal effort was required to disengage the connector from the ACM. Inspection of the connector and the pin port of the ACM revealed surface corrosion (green in color) to the mid area of the pins **(Figure 14)**. No pins were bent or damaged.

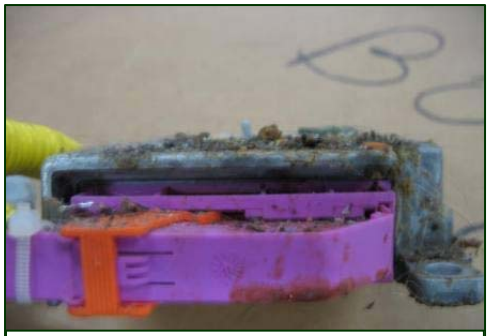

Figure 13. Purple connector.

Figure 14. Corrosion at mid point of connector and pins.

Occupant Data

2001 Hyundai Elantra

Driver:	18-year old male
Height:	191 cm (75 in)
Weight:	99 kg (219 lb)
Manual Restraint Usage:	Three-point lap and shoulder belt
Usage Source:	Loading evidence
Eyewear:	None
Seat Track Position:	Rear track
Driver Outcome:	Fatal

Driver Injuries

Injury	Injury Severity AIS90/Update 98	Injury Source
Subdural hemorrhage overlying the pons, mid-brain, and cerebellum with associated subarachnoid hemorrhage around base of the brain	Critical (140210.5,8)	Non contact – flexion of head from impact forces
Fracture with displacement of atlanto-occipital joint with compression of the spinal cord	Severe (640218.4,6)	Non contact – flexion of head from impact forces
Multiple cerebral hemorrhages of the white matter of the corpus callosum	Severe (140629.4,9)	Non contact – flexion of head from impact forces
Contusion to posterior aspect of left lung	Serious (441406.3,2)	Rebound injury into the left B-pillar
Multiple mesenteric contusions to the serosa of the large intestine near the appendix and over the sigmoid colon and the pubic brim	Moderate (542010.2,8)	Lower steering wheel rim
Fractured right pelvis to the ilio-ischial ramus	Moderate (852602.2,1)	Indirect from knee impact with the left instrument panel
Abrasion, laceration, and contusion to the inguinal region of the lower abdomen	Minor (590202.1,8) (590402.1,8) (590602.1,8)	Lower steering wheel rim
Heart contusion to the	Minor (441002.1,4)	Non-deployed air bag

epicardial surface at the apex and near the origin of the great vessels		module/steering wheel hub
2.5 cm (1") laceration to lower lip	Minor (290602.1,8)	Upper steering wheel rim
Fractured right mandible	Minor (250606.1,1)	Upper steering wheel rim
1.5 cm (0.6") scalp laceration; behind left ear	Minor (190602.1,2)	Rebound injury into the left upper B-pillar
*Multiple abrasions to posterior neck	Minor (390202.1,6)	Unknown
*Multiple abrasions to the back aspect of the left forearm	Minor (790202.1,2)	Unknown
Multiple abrasions to the back aspect of the right hand	Minor (790202.1,1)	Center instrument panel
Multiple abrasions and contusions to the bilateral knees	Minor (890202.1,3) (890402.1,3)	Lower left instrument panel (knee bolster)

* Supplemental Note: *The posterior neck abrasions were not visible in the on-scene police images of the driver. His posterior neck area was shielded by an integrated hood on his jacket. There were no glass fragments in the hood. His left forearm was covered by two layers of clothing, inclusive of a heavy-weight jacket. It is possible that these abrasions were not related to the crash.*

Driver Kinematics

The 18-year old male driver of the Hyundai was seated in an upright posture in a rear track position. His head restraint was adjusted to the full-down position. He was dressed in white painter-type pants, a T-shirt, a long-sleeve sweat shirt, and a hooded canvas-type jacket. The jacket was unzipped. The driver was restrained by the manual safety belt system. Belt usage was verified by frictional abrasions at the D-ring and belt webbing **(Figure 15)**, and frictional abrasions on the lap belt aspect of the belt from engagement against the latch plate. A 6 mm (0.25") cut was noted to the belt at the latch plate location.

The driver responded to the frontal impact force by initiating a forward trajectory. He loaded the manual safety belt system, evidenced by the abrasions noted above. He continued to move forward and engaged the lower aspect of the steering wheel rim, deforming the four-spokes and the flange resulting in mesenteric contusions to the serosa of the large intestine. In addition to the spoke deformation, the driver's chest loaded the non-deployed air bag module resulting in a heart contusion. This loading force was transferred into the steering column which compressed the energy absorbing column 6 cm (2.5").

His knees and lower legs engaged the rearward intruding instrument panel and knee bolster. His left knee fractured the plastic fuse box cover and the mid instrument panel **(Figure 16)**. The driver's right knee fractured the mid panel right of the steering column. He sustained multiple abrasions and contusions over the knees. The loading force was transmitted through the femurs resulting in an induced fracture of the right pelvis to the ilio-ischial ramus. The driver's inguinal area engaged the lower steering wheel rim resulting in abrasions, a laceration, and contusion of the lower abdomen.

The safety belt and steering wheel rim arrested the forward motion of the driver's torso. His head continued forward with flexion of the neck. This impact induced motion of the head resulted in subdural and subarachnoid hemorrhages, a fracture of the atlanto-occiptal joint with compression of the spinal cord, and multiple cerebral hemorrhages. The driver's lower face subsequently impacted the top surface of the steering wheel rim resulting in a laceration of the lower lip and a fracture of the right mandible.

The posterior aspect of the driver's right hand impacted the center instrument panel resulting in abrasions to the dorsum of the hand.

The driver rebounded into the left B-pillar sustaining a contusion to the posterior aspect of the left lung and a 1.5 cm scalp laceration behind the left ear. The autopsy report identified abrasions of the posterior neck and of the left forearm. These body areas were protected by heavy clothing, therefore the source of these injuries were unknown. The posterior neck abrasions were not visible in the on-scene police images.

The driver succumbed to his injuries at the scene of the crash. His body was removed from the vehicle and transported to the morgue for autopsy.

Figure 15. Frictional abrasion on belt webbing and D-ring.

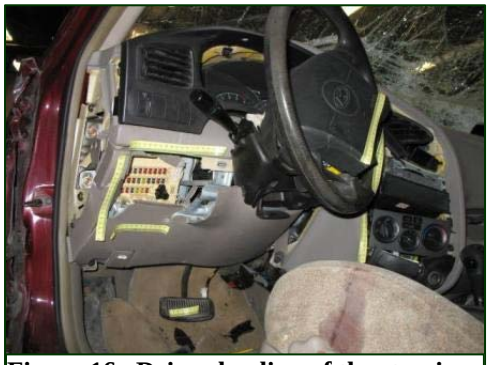

Figure 16. Driver loading of the steering assembly and the mid instrument panel.

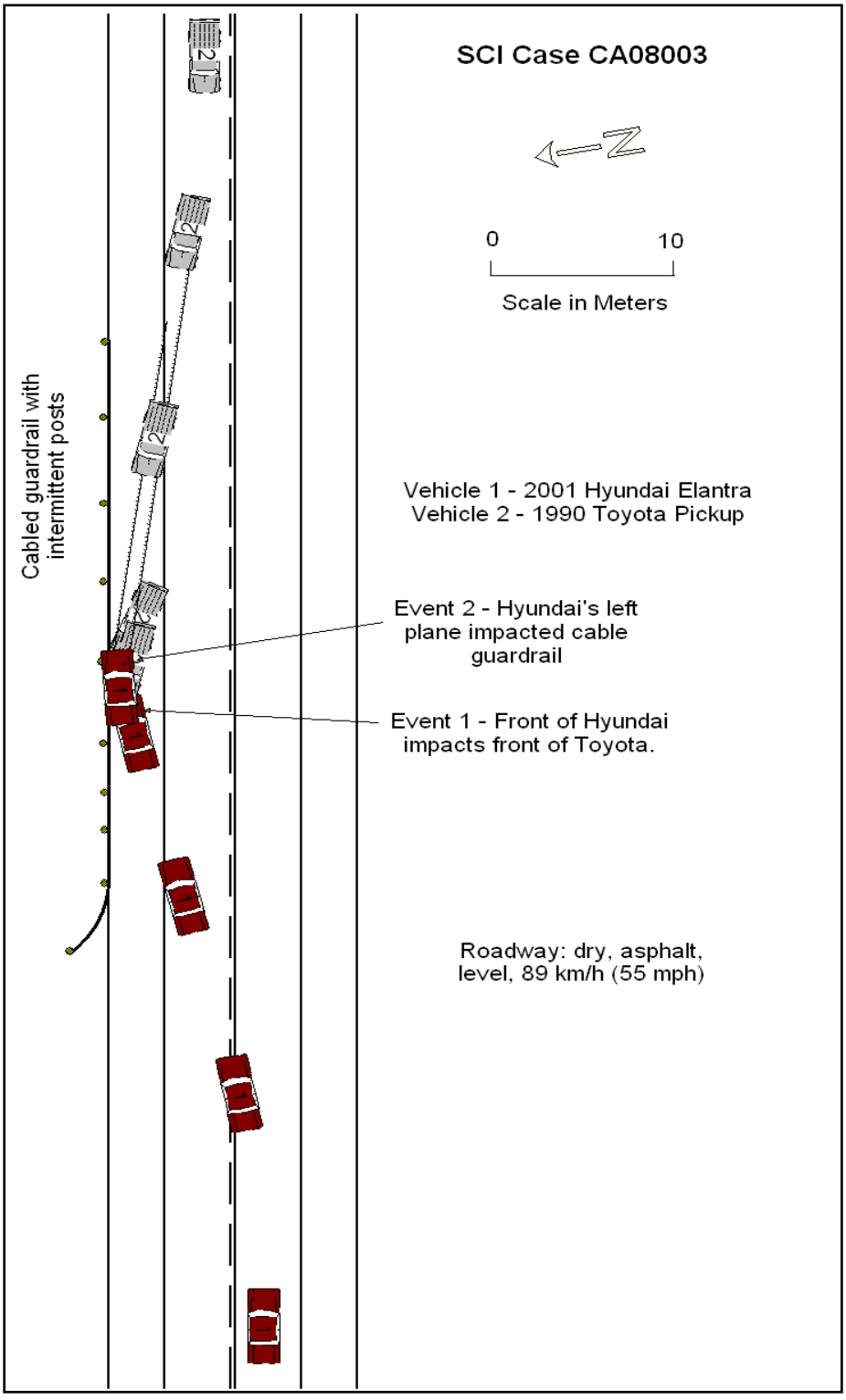

Figure 17: Scene Schematic