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ON-SITE CHILD SAFETY SEAT INVESTIGATION

CASE NUMBER - IN-05-003

LOCATION - TEXAS

VEHICLE - 1999 HYUNDAI ELANTRA GL

CRASH DATE - December 2004

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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 performance of the involved vehicle(s) or their safety systems.

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15. <i>Supplementary Notes</i> On-site child safety seat investigation involving a 1999 Hyundai Elantra GL with manual safety belts and dual redesigned front air bag system.					
16. <i>Abstract</i> This report covers an on-site crash investigation that involved a 1999 Hyundai Elantra GL (case vehicle), a Freightliner tractor semi-trailer (1 st other vehicle) and a 1994 GMC C1500 pickup truck (2 nd other vehicle). This crash is of special interest because the case vehicle's back center passenger [2-month-old, male] was restrained in a rear facing infant seat and survived this very severe rear-end impact crash. The case vehicle, Freightliner, and GMC were traveling eastbound on a multi-lane, divided Interstate highway. The Freightliner was traveling in the inside lane and was behind the case vehicle. The case vehicle and GMC were traveling in the center lane. The GMC was in front of the case vehicle. A dog ran into the roadway from the right. Traffic in all three lanes began to slow and change lanes. A non-contact vehicle swerved left into the inside lane in front of the Freightliner. The Freightliner swerved to the right into the center lane to avoid the non-contact vehicle at the same time the case vehicle and GMC were braking hard for traffic slowing in front of them. The front of the Freightliner impacted the back of the case vehicle. The Freightliner stayed in contact with the case vehicle and pushed it into the back of the GMC. The front right of the case vehicle impacted and underrode the back left of the GMC. The Freightliner impact to the back of the case vehicle caused the case vehicle to rapidly rotate counterclockwise as it underrode the GMC, and the case vehicle's right front side impacted the GMC's back right corner. The case vehicle rotated counterclockwise and came to rest partially across the center and outside travel lane facing south. The GMC rotated clockwise and came to rest in the center travel lane facing south with the back of the vehicle partially in the inside travel lane. The Freightliner continued east, pulled off the roadway and stopped on the outside shoulder. The case vehicle's back center passenger was restrained in his rear-facing infant seat. The infant seat was extensively deformed during the crash due to intrusion. The back center passenger sustained two small occipital fractures, small subdural and subarachnoid hemorrhages and a nonanatomic brain injury due to contact with the back of his infant seat, as well as a fractured left femur. He was hospitalized for one day. The driver was restrained and sustained a fractured left clavicle from her safety belt and contusions to her lower left leg and ankle. She was treated and released from the emergency room.					
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This investigation was brought to NHTSA's attention on or before December 7, 2004 by an article in a Texas newspaper. This crash involved a 1999 Hyundai Elantra GL (case vehicle), a Freightliner tractor semi-trailer (1st other vehicle), and a 1994 GMC C1500 pickup truck (2nd other vehicle). The crash occurred in December, 2004, at 2:04 p.m., in Texas and was investigated by the applicable city police department. This crash is of special interest because the case vehicle's back center passenger [2-month-old, White (non-Hispanic) male] was seated in a rear-facing infant seat and survived this very severe rear-impact crash. This contractor completed the scene, vehicle and infant seat inspections, and interviewed the case vehicle's driver on January 12-14, 2004. This report is based on the police crash report; scene, vehicle and infant seat inspections; interview with the case vehicle's driver, medical records, occupant kinematic principles, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle, Freightliner, and GMC were traveling eastbound on a multi-lane, divided Interstate highway. The Freightliner was traveling in the inside lane and was behind the case vehicle. The case vehicle and GMC were traveling in the center lane. The GMC was in front of the case vehicle. A non-contact vehicle was also in the center lane and was behind the case vehicle. A dog ran into the roadway from the right. Traffic in all three lanes began to slow and change lanes. The non-contact vehicle swerved left into the inside lane in front of the Freightliner. The Freightliner swerved to the right into the center lane to avoid the non-contact vehicle at the same time the case vehicle and GMC were braking hard for traffic slowing in front of them. The front of the Freightliner impacted the back of the case vehicle. The Freightliner stayed in contact with the case vehicle and pushed it into the back of the GMC. The front right of the case vehicle impacted and underrode the back left of the GMC. The Freightliner's impact to the back of the case vehicle caused the case vehicle to rapidly rotate counterclockwise as it underrode the GMC, and case vehicle's right front side impacted the GMC's back right corner. The case vehicle's front impact to the GMC did not cause the case vehicle driver's air bag to deploy. It is not known why the air bag did not deploy. The case vehicle rotated counterclockwise and came to rest partially across the center and outside travel lane facing south. The GMC rotated clockwise and came to rest in the center travel lane facing south with the back of the vehicle partially in the inside travel lane. The Freightliner continued east, pulled off the roadway and stopped on the outside shoulder.

The CDCs for the case vehicle were determined to be: **07-BDAW-7 (200 degrees)** for the rear impact with the Freightliner, **12-FZEW-2 (10 degrees)** for the frontal impact with the back left of the GMC, and **04-RYEW-3 (120 degrees)** for the right front impact with the back right corner of the GMC. The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's Delta V because an impact with a heavy truck is out-of-scope for the WinSMASH program as is a "chain reaction", sustained contact collision such as this crash. However, the WinSMASH program was used to determine a barrier equivalent speed (BES) based on the residual crush to the case vehicle. The BES for the impact to the back of the case vehicle was 79.8 km.p.h. (49.6 m.p.h.). The BES for the impact to the front of the case vehicle was 27.3 km.ph. (17.0 m.p.h.). The case vehicle was towed due to damage.

Based on the police on-scene photographs of the damage to the Freightliner, the TDC was estimated to be: **12-FYEW-2**. The Freightliner was towed due to damage.

The CDCs for the GMC were determined to be: **06 BYEW-1 (180 degrees)** and **06-BZEW-1 (170 degrees)**. The WinSMASH reconstruction program could not be used to reconstruct the GMC's Delta V because "chain reaction", sustained contact collisions such are out of scope of the program.

The back center passenger was seated in an infant seat that was being used without the base in the rear-facing configuration. The infant seat was manufactured by Graco Children's Products on November 8, 2003 and was identified by model name "Snug Ride," model number 7320UVB, and serial number JJ1108030835. The infant seat was purchased new in August, 2004 and was used on a daily basis. The infant seat consisted of a one piece plastic shell with light, closed-cell foam padding at the head and shoulder area and a padded pullover cloth cover. It was designed with a three-point harness with a recessed latch plate fixed to the base of the infant seat. The harness buckle was attached to the end of the two shoulder straps, and the harness retainer clip was positioned approximately at the infant's armpit level. The harness straps were threaded through the bottom slots. The infant seat was secured tightly in the case vehicle's back center seat position by the vehicle's two-point lap belt, which was routed through the guides on the top of both sides of the infant seat. The infant seat was severely bent and deformed during the crash due to intrusion of the case vehicle's rear seat back.

The case vehicle's driver indicated that she had installed the infant seat in the vehicle and placed the infant in the seat. She indicated there was nothing placed under the infant seat to position it. She further stated that besides normal clothes, there was nothing between the child's chest and the harness straps, and that "one finger" could be placed in this space.

The Freightliner's impact to the back of the case vehicle caused the back center passenger to move rearward and to the left opposite the case vehicle's 200 degree direction of principal force as the case vehicle was accelerated forward, and he loaded his three-point infant seat harness. He also rebounded back into the infant seat and simultaneously moved forward and right opposite the case vehicle's 10 degree direction of principal force when the case vehicle impacted the back of the GMC. The back of infant's head impacted the infant seat's top back surface causing two small occipital fractures, small subdural and subarachnoid hemorrhages and a nonanatomic brain injury. The crush to the back of the case vehicle caused the case vehicle's rear seat and seat back to intrude forward, forcing the infant seat forward and wedging it into and between the rear seat back and the two front seat backs and center console. During this phase of the crash, the lower portion of the infant seat was thrust upward, in essence "jackknifing" the infant seat and fracturing the infant's left femur. The back center passenger then moved to the right in his infant seat as the back right corner of the GMC impacted the case vehicle's right front side. The infant was entrapped in his infant seat due to the intrusion of the rear seat back.

The infant was removed from the case vehicle by rescue personnel and transported by ambulance to a hospital and was treated and released. Due to his continued crying, he was taken back to the hospital where his injuries were diagnosed and he was hospitalized for one day.

Immediately prior to the crash, the case vehicle's driver (18-year-old, female) was seated in an upright posture with her back against the seat back, her left foot on the floor and her right foot on the brake. She was gripping the steering wheel and bracing due to the hard braking for the GMC that was slowing in front of her. Her seat track was located in its middle position, the seat back was slightly reclined, and the tilt steering wheel was located in its center position. The driver was restrained by her manual, three-point, lap-and-shoulder safety belt.

As a result of the pre-impact braking, the driver's safety belt retractor most likely locked, and she moved forward loading her safety belt. The Freightliner's impact to the back of the case vehicle caused the driver to move rearward and left opposite the case vehicle's 200 degree direction of principal force as the case vehicle was accelerated forward. The driver impacted the left side of her head on the "B"-pillar lacerating her scalp and causing a nonanatomic brain injury with loss of consciousness. Her seat back was initially displaced rearward, but was subsequently forced forward due to the dynamic intrusion of the rear seat back and loading of her seat back by the infant seat. The case vehicle's subsequent front right impact with the back left of the GMC then caused the driver to move forward and to the right opposite the case vehicle's 10 degree direction of principal force as the case vehicle decelerated. The driver loaded her safety belt fracturing her left clavicle, her right shin contacted the intruding knee bolster bruising her shin, and her right ankle contacted the foot controls bruising her ankle. The driver remained restrained in her seat, and her upper torso most likely moved to her right and back opposite the case vehicle's 120 degree direction of principal force as the GMC's back right corner was impacted by the case vehicle's right front side. The driver remained restrained in her seat as the case vehicle came to final rest. She was entrapped in the case vehicle by the intruded instrument panel and the downwardly displaced steering wheel. Rescue personnel removed the driver's door, and B-pillar, and cut her safety belt and the steering wheel rim to extricate her from the vehicle.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which all vehicles were traveling was a straight, six-lane, divided Interstate highway (**Figure 1**), traversing in an east-west direction. Each travel direction contained three travel lanes bordered by wide inside and outside improved shoulders. Each travel lane was approximately 3.7 meters (12 feet) wide. Each shoulder was approximately 3.1 meters wide (10 feet). The trafficway was divided by a concrete median barrier. Roadway pavement markings consisted of broken white lane lines with solid white outside edge lines and solid yellow median edge lines. The roadway pavement was dry, travel polished bituminous with an estimated coefficient of friction of 0.70. The speed limit was 97 km.p.h. (60 m.p.h.), and the involved roadway had an approximate 4% negative grade. At the time of the crash the light condition was daylight and the atmospheric condition was clear.

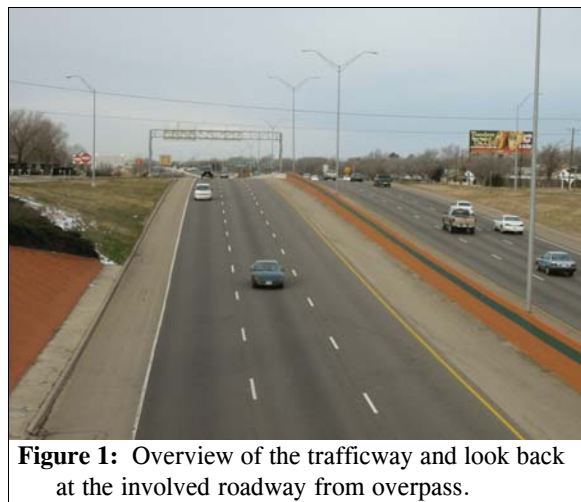


Figure 1: Overview of the trafficway and look back at the involved roadway from overpass.

Traffic density was moderate, the crash site was within an interchange area and the area around the crash site was a combination of residential/commercial. See the Crash Diagram at the end of this report.

Pre-Crash: The case vehicle was traveling east in the center lane (**Figure 2**), and the driver was intending to continue straight ahead. The Freightliner was traveling east in the inside lane and was approaching the case vehicle. The Freightliner's driver was intending to continue straight ahead. The GMC was traveling east in the center lane in front of the case vehicle. The GMC's driver was intending to continue straight ahead. A non-contact vehicle was also traveling east in the center lane and was behind the case vehicle. According to the police crash report and a local newspaper article, a dog ran into the roadway from the right. Traffic in all three lanes began to slow and change lanes. The non-contact vehicle swerved left into the inside lane in front of the Freightliner. The Freightliner swerved to the right into the center lane to avoid the non-contact vehicle at the same time the case vehicle and GMC were braking hard for traffic slowing in front of them. The Freightliner began to close on the case vehicle. The crash occurred in the center lane of the roadway.



Figure 2: Approach of case vehicle and GMC eastbound in the center lane



Figure 3: Overview of damage to front of Freightliner from impact with back of case vehicle

Crash: The front of the Freightliner (**Figure 3**) impacted the back of the case vehicle (**Figure 4**). The Freightliner stayed in contact with the case vehicle and pushed it into the back of the GMC. The front right of the case vehicle (**Figure 5** below) impacted and underrode the back left of the GMC (**Figure 6** below). The Freightliner impact to the back of the case vehicle caused the case vehicle to rapidly rotate counterclockwise as it underrode the GMC, and case vehicle's right front side impacted the GMC's back right corner (**Figure 7** below). This impact crushed the case vehicle's cowl and lower right A-pillar inward and damaged the front portion of the right front door



Figure 4: Right side overview of damage to back and front of the case vehicle

(Figure 8). The front impact to the case vehicle did not cause the driver's air bag to deploy. It is not known why the air bag did not deploy.



Figure 5: Direct damage to front right of case vehicle (arrows) due to impact with the back left of the GMC, each stripe on rods is 5 cm (2 in)



Figure 6: Direct damage to back left of GMC (arrows) due to impact with front right of case vehicle



Figure 7: Damage to GMC back right corner due to impact with case vehicle's right front side

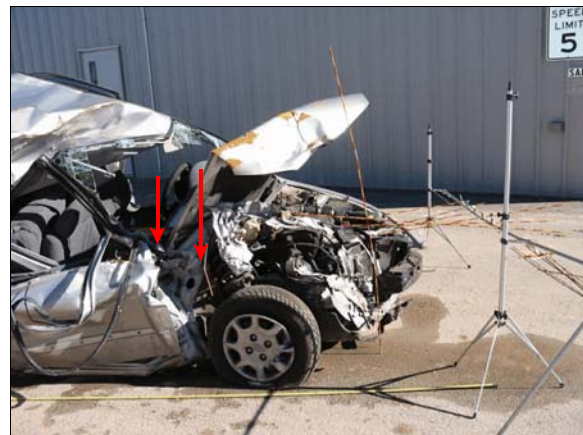


Figure 8: Damage to case vehicle's right front side (arrows) due to impact with back right of GMC

Post-Crash: The case vehicle rotated counterclockwise and came to rest partially across the center and outside travel lane facing south. The GMC rotated clockwise and came to rest in the center travel lane facing south with the back of the vehicle partially in the inside travel lane. The Freightliner continued east, pulled off the roadway and stopped on the outside shoulder (Figure 9 below).

CASE VEHICLE

The 1999 Hyundai Elantra GL was a front wheel drive, four-door sedan (VIN: KMJHF25F1XU-----) equipped with a 2.0L, I4 engine and three speed automatic transmission. The front seating row was equipped with bucket seats with adjustable head restraints, redesigned driver and front right passenger air bags and manual, three-point lap and shoulder safety belts. The back seating row was equipped with a bench seat with manual, three point, lap and shoulder safety belts in the outboard seating positions and a two point lap belt in the

center seat position. It is unknown if the case vehicle was equipped with anti-lock brakes. The case vehicle’s wheelbase was 255 centimeters (100.4 inches). The odometer reading at the time of the vehicle inspection was 185,317 kilometers (115,154 miles).

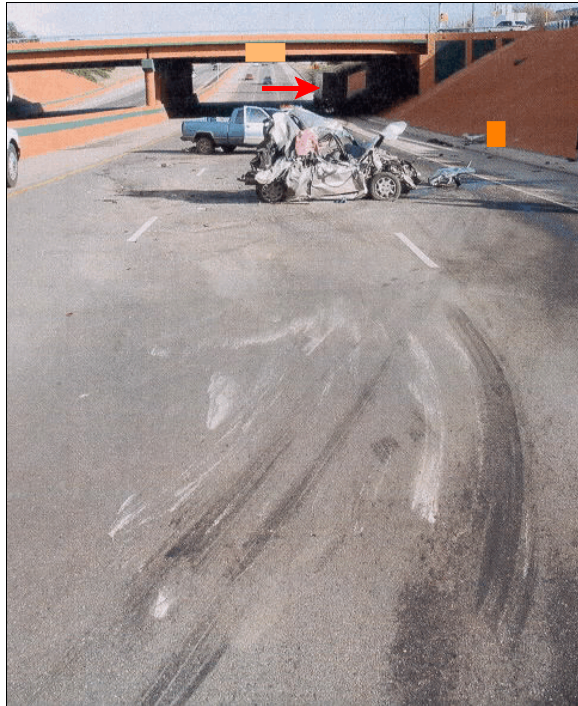


Figure 9: View east to final rest position of case vehicle, GMC and Freightliner (arrow), impact tire marks and scratches on pavement in foreground

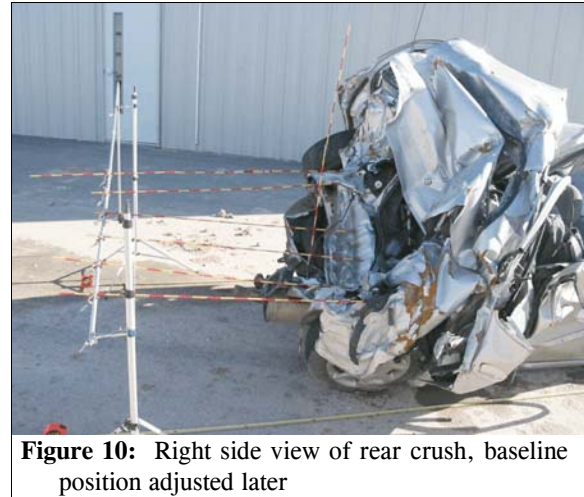


Figure 10: Right side view of rear crush, baseline position adjusted later

CASE VEHICLE DAMAGE

Exterior Damage: The case vehicle’s initial contact with the Freightliner involved the entire rear plane. Direct damage was distributed across the entire horizontal and vertical dimensions of the back of the case vehicle, and the back end was extensively crushed forward (**Figure 10**). Direct

damage began at the back left corner of the case vehicle and extended 109 centimeters (43 inches) across the damaged back plane of the vehicle. The back bumper had been knocked off the case vehicle and was not available at the inspection, so crush measurements were taken on the body panel immediately behind the back bumper mounting brackets. Adjustments were subsequently made for baseline placement, and to account for the missing bumper based on measurements of an exemplar vehicle. The residual maximum crush was determined to be approximately 120 centimeters (47 inches) occurring at C₁ (**Figure 10**). The table below shows the case vehicles back plane crush profile.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	109	25	109	120	114	120	118	104	101	0	0
in		42.9	9.8	42.9	47.2	44.9	47.2	46.5	40.9	39.8	0.0	0.0

The case vehicle’s impacts with the GMC involved the front plane, right front wheel, fender, cowl, lower A-pillar and door area. The direct damage to the front of the case vehicle started at

the right front bumper corner and extended 53 centimeters (20.9 inches) across the front of the case vehicle. The front bumper, grille, hood, right turn signal/headlamp assemblies, right front wheel, and right fender were all directly damaged and crushed rearward. Adjustments were subsequently made for baseline placement, and the residual maximum crush at the front bumper was determined to be 18 centimeters (7.1 inches) occurring at C₆. A second level of crush measurements were taken above the bumper level due to the underride damage. The residual maximum crush at this level was determined to be 64 centimeters (25.2 inches), also occurring at C₆ (Figure 8 above). Crush measurements were not obtained for the right front damage due to overlapping damage from the front impact. The table below shows the average of the case vehicle’s bumper level and above bumper level crush values.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	53	64	102	0	0	4	15	28	41	40	0
in		20.9	25.2	40.2	0.0	0.0	1.6	5.9	11.0	16.1	15.7	0.0

The wheelbase on the case vehicle’s left side was shortened 42 centimeters (16.5 inches) while the right side wheelbase was shortened 37 centimeters (14.6 inches). The entire vehicle sustained induced damage.

The case vehicle’s recommended tire size was P195/60R14. The case vehicle was equipped with P195/60R14 size tires on the left front, right front and left rear, and a P175/60R14 size tire on the right rear. The case vehicle’s tire data are presented in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 nd of an inch			
LF	200	29	207	30	7	9	None, but gravel/asphalt in rim	No	No
RF	0	0	207	30	7	9	Sidewall abraded, rim damaged	No	Yes
LR	117	17	207	30	4	5	None	No	No
RR	179	26	207	30	3	4	None	No	No

Vehicle Interior: Inspection of the case vehicle’s interior revealed probable occupant contact to the knee bolster and steering wheel. The driver’s right knee bolster had intruded and reduced nearly all the space available to the driver’s right leg. The steering column had moved downward during the crash and was resting on the driver’s seat cushion, indicating it probably contacted one

or both of the driver's thighs (**Figure 11**). The steering wheel rim had been cut by rescue personnel. Blood stains were noted on driver's seat back and head restraint. This was most likely related to the laceration the driver sustained to left side of her head. The driver's shoulder belt had been cut by rescue personnel, indicating the driver was wearing her safety belt at the time of the crash. No other occupant contacts were noted.

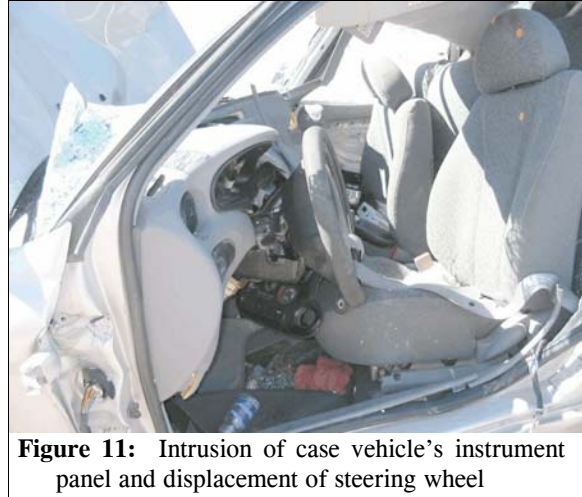


Figure 11: Intrusion of case vehicle's instrument panel and displacement of steering wheel

There was extensive intrusion to the case vehicle's interior. The most severe intrusions relative to the infant in the back center seat position involved the back seat row seat backs.

They had intruded forward approximately 105 centimeters (41.3 inches) into the back center and back right seat positions, and approximately 80 centimeters (31.5 inches) into the back left seat position. Other intrusions involved both A-pillars, the instrument panel, steering wheel, both B-pillars, both C-pillars, the backlight header and the roof.

Damage Classification: Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **07-BDAW-7 (200 degrees)** for the rear impact with the Freightliner, **12-FZEW-2 (10 degrees)** for the frontal impact with the back left of the GMC, and **04-RYEW-3 (120 degrees)** for the right front impact to the back right of the GMC. The WinSMASH reconstruction program could not be used to reconstruct the case vehicle's Delta V because an impact with a heavy truck is out-of-scope for the WinSMASH program as is a "chain reaction", sustained contact collision such as this crash. However, the WinSMASH program was used to determine an barrier equivalent speed (BES) based on the case vehicle's residual crush. The BES for the impact to the back of the case vehicle was 79.8 km.p.h. (49.6 m.p.h.). The BES based on the impact to the front of the case vehicle was 27.3 km.ph. (17.0 m.p.h.). A BES for the right front damage to the case vehicle could not be determined due to overlapping damage. The case vehicle was towed due to damage.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with redesigned air bags at the driver and front right passenger positions. The case vehicle's driver air bag was located in the steering wheel hub and the front right passenger air bag was located in the middle of the front right instrument panel, above the glove box door. Neither of these air bags deployed as a result of the crash. The front impact appeared to be significant enough to require a driver air bag deployment. It is unknown why a deployment did not occur. Reference material indicates a 30 second discharge time for the air bag module capacitor, which would appear to rule out a non-deployment due to possible disruption of the electrical system from the underride damage. The driver stated the vehicle had been in no other crashes while she owned it. She indicated she had bought the vehicle used. The history of the case vehicle prior to the current owner is not known.

The back center passenger was seated in an infant seat (**Figure 12**) that was being used without the base in a rear-facing configuration. The infant seat was manufactured by Graco Children's Products on November 8, 2003 and was identified by model name "Snug Ride," model number 7320UVB, and serial number JJ1108030835. The infant seat was purchased new in August, 2004 and was used on a daily basis. The infant seat consisted of a one piece plastic shell with light, closed-cell foam padding at the head and shoulder area and a padded pullover cloth cover. It was designed with a three-point harness with a recessed latch plate fixed to the base of the infant seat. The harness buckle was attached to the end of the two shoulder straps, and the harness retainer clip was positioned approximately at the infant's armpit level. A carrying handle was attached to both sides of the infant seat. There were two sets of harness adjustment slots in the seat back. The harness straps were threaded through the bottom slots.



Figure 12: Overview of front of infant seat

The infant seat was secured tightly in the case vehicle's back center seat position by the vehicle's lap belt, which was routed through the guides on the top of both sides of the infant seat. The infant seat was not equipped with a LATCH system. The infant seat base, which was not in use, was equipped with the LATCH components.

The case vehicle driver indicated that she had read the infant seat's instruction manual, but was not aware of any instructions in the vehicle owner's manual regarding securing child safety seats in the vehicle. The driver indicated that she had installed the infant seat and placed the infant in the seat prior to the crash. The infant seat was placed in the case vehicle in the rear-facing, reclined position with the carrying handle folded back. She indicated there was nothing placed under the infant seat to position it. She further stated that besides normal clothes, there was nothing between the child's chest and the harness straps, and that "one finger" could be placed in this space.

Inspection of the infant seat revealed numerous stress marks in the plastic shell indicating the infant seat had been bent during the crash as a result of the intrusion of the case vehicle's rear seat back. The plastic shell of the infant seat was dark blue. The areas of stress where the infant seat had bent and deformed exhibited a light blue color in the plastic. These stressed areas were observed on the bottom, and inside bottom portion of the infant seat running the entire width of the seat (**Figures 13** and **14** below), and radiating on to each side. Both sides of the seat exhibited stress mark discoloration and deformation with the left side of the seat being deformed the most. More vertical stress marks were observed on both edges of the infant seat back, above the head

area, and there was an abrasion on the right outer edge. In addition, the case vehicle’s lap belt had left a load abrasion on the left side of the infant seat. The stress and deformation pattern on the infant seat, as well as a photograph of the infant seat still in the case vehicle (**Figure 15**) showed that the infant seat had deformed in a “jackknife” type configuration during the crash. This was due to the intrusion of the case vehicle’s rear seat back, which bent the bottom of the infant seat upward as the infant seat was entrapped between the case vehicle’s intruding rear seat back and the front seat backs and center console. The bending produced a crack in the bottom left side of the infant seat. In addition, the right harness strap anchor was missing (**Figure 13**); however, it did not appear to have been pulled out of the back of the seat. It was not with the seat during the inspection. The left harness strap was separated (**Figure 13** and **Figure 16** below). It did not exhibit a clean cut like the driver’s safety belt. It had ragged strands of webbing fibers on each side of the webbing on one end, which is consistent with a broken belt. The other end appeared stretched; however, it also appeared to have been cut. The separation was determined not to be the result of deformation to the seat. In addition, there were no injuries to the infant indicating heavy loading of the harness strap. The separation is assumed to be the result of rescue personnel cutting and pulling on the harness strap.



Figure 13: Back of infant seat showing stress marks on bottom of seat, harness strap and missing harness anchor (arrow)



Figure 14: Deformation to bottom section of the infant seat



Figure 15: Family photograph of infant seat in back seat of case vehicle jammed between intruded rear seat back and front seat backs, arrow shows bent bottom portion of seat, photo from left side of car

There were several warning and instruction labels affixed to both sides of the seat in English and Spanish. The manufacturer’s warning label giving the infant seat’s weight limitations indicated to use the infant seat only in a rear-facing position

with children who weigh 20 pounds (9 kilograms) or less and whose height is 26 inches (66 centimeters) or less. The label also stated to, “Secure this child restraint with the vehicle’s child restraint anchorage system (LATCH) if available or with a vehicle belt”. Illustrations were also on the label showing proper installation using a vehicle’s lap or lap-and-shoulder belt when the seat was used with or without the base.

CASE VEHICLE BACK CENTER PASSENGER KINEMATICS

Immediately prior to the crash the case vehicle's back center passenger [2-month-old, White (non-Hispanic) male; [53 centimeters and 5.9 kilograms (21 inches, 13 pounds)] was seated in his rear facing infant seat. His feet were contained within the infant seat and his arms were in an unknown position. The case vehicle’s back seat had no seat track and the seat back was not adjustable.

The case vehicle's back center passenger was restrained in his infant seat by the three point harness. The harness retainer clip was positioned approximately at the infant’s armpit level, and the infant seat was secured to the case vehicle’s seat by the two-point lap belt. The case vehicle’s driver indicated she secured the infant seat by routing the lap belt through the safety belt guides on the top of the infant seat and pulling the lap belt tight. Inspection of the infant seat revealed a safety belt abrasion on the left side of the infant seat just below the safety belt guide (**Figure 17**) indicating the infant seat was secured as she stated. Also, the case vehicle’s back center lap belt had been cut by rescue personnel further indicating it was in use with the infant seat.

The case vehicle's driver stated she locked the brakes immediately prior to the Freightliner impacting the back of the case vehicle. As a result of the braking, the back center passenger moved forward into the back of his rear facing infant seat. The Freightliner impact to the back of the case vehicle then caused the back center passenger to move rearward and to the left opposite the case vehicle’s 200 degree direction of principal force as the case vehicle was accelerated forward, and he loaded his three-point infant seat harness. He also rebounded back into the infant seat and simultaneously moved forward and right opposite the case vehicle’s 10 degree direction of principal force when the case vehicle impacted the back of the GMC. The back of infant’s head



Figure 16: Separated ends of the infant seat’s left harness strap, arrow shows ragged strands of webbing fibers on edges of strap

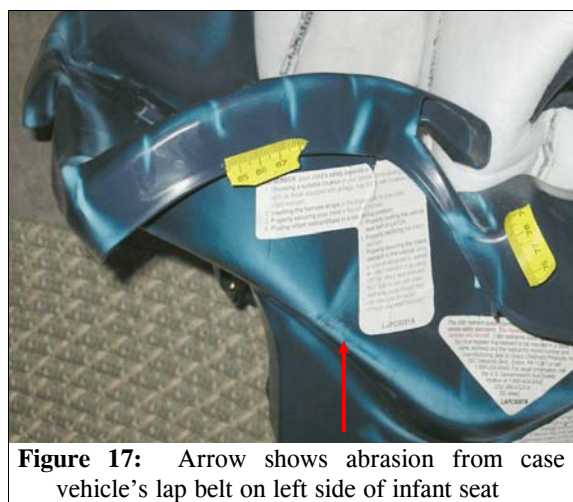


Figure 17: Arrow shows abrasion from case vehicle’s lap belt on left side of infant seat

impacted the infant seat’s top back surface causing two small occipital fractures, small subdural and subarachnoid hemorrhages and a nonanatomic brain injury. The crush to the back of the case vehicle caused the case vehicle’s rear seat and seat back to intrude forward, forcing the infant seat forward and wedging it into and between the rear seat back, the two front seat backs and center console. During this phase of the crash, the lower portion of the infant seat was thrust upward, in essence “jackknifing” the infant seat and fracturing the infants’s left femur. The infant was entrapped in his infant seat due to the intrusion of the rear seat back. The infant was removed from the case vehicle by rescue personnel.

CASE VEHICLE BACK CENTER PASSENGER INJURIES

The infant was transported by ambulance to a hospital and was treated and released. Due to his continued crying, he was taken to back to the hospital and his injuries were diagnosed. He was admitted and spent one day in the hospital. The table below shows the back center passenger’s injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Hemorrhage, subdural, small, over right posterior fossa	severe 140652.4,1	Child safety seat’s back top surface	Probable	Hospitalization records
2	Hemorrhage, subarachnoid, small, right occipital or posterior-parietal area	serious 140684.3,1	Child safety seat’s back top surface	Probable	Hospitalization records
3	Hemorrhage, subarachnoid, over left posterior or parietal convexity	140684.3,2			
4	Fracture, non-displaced, small, on right occipital and/or posterior parietal skull	serious 150200.3,8	Child safety seat’s back top surface	Probable	Hospitalization records
5	Fracture, small, left occipital with overlying scalp hematoma left temporal region	moderate 150402.2,6	Child safety seat’s back top surface	Probable	Hospitalization records
6	Fracture left femur, non-displaced, not specified as to location but most likely distal	serious 851800.3,2	Seat back, back center passenger’s {Indirect injury}	Probable	Emergency room records
7	Nonanatomic brain injury–unknown with respect to prior unconsciousness, but vomiting	minor 160402.1,0	Child safety seat’s back top surface	Probable	Emergency room records
8	Contusion {hematoma/bruising} left temporal region	minor 190402.1,2	Child safety seat’s back top surface	Probable	Hospitalization records

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
9	Contusion { hematoma }, sub-galeal, right posterior-parietal scalp	minor 190402.1,6	Child safety seat's back top surface	Probable	Hospitalization records
10	Contusions {bruising} on back of legs, not further specified	minor 890402.1,3	Child safety seat's front bottom surface	Probable	Emergency room records

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash, the case vehicle's driver [18-year-old, White (non-Hispanic) female; (160 centimeters and 61 kilograms (63 inches, 135 pounds))] was seated in an upright posture with her back against the seat back, her left foot on the floor and her right foot on the brake. She was gripping the steering wheel and bracing due to hard braking for the GMC that was slowing in front of her. Her seat track was located in its middle position, the seat back was slightly reclined, and the tilt steering wheel was located in its center position.

The case vehicle's driver was restrained by her manual, three-point, lap-and-shoulder safety belt system. The driver's safety belt webbing was cut by rescue personnel, and inspection of the belt revealed the webbing to have a stretched, wavy appearance indicating it had been loaded by the driver during the crash. In addition, the driver sustained a fractured left clavicle in the crash from loading her shoulder belt.

The case vehicle's driver stated she locked the brakes immediately prior to the Freightliner impacting the back of the case vehicle. As a result of the braking, her seat belt retractor most likely locked, and she moved forward loading her safety belt. The Freightliner's impact to the back of the case vehicle caused the driver to move rearward and left opposite the case vehicle's 200 direction of principal force as the case vehicle was accelerated forward. The driver impacted the left side of her head on the left "B"-pillar lacerating her scalp and causing a nonanatomic brain injury with loss of consciousness. Her seat back was initially displaced rearward, but was subsequently forced forward due to the dynamic intrusion of the rear seat back and loading of her seat back by the infant seat. The case vehicle's subsequent front right impact with the back left of the GMC caused the driver to move forward and to the right opposite the case vehicle's 10 degree direction of principal force as the case vehicle decelerated. The driver loaded her safety belt fracturing her left clavicle, her right shin contacted the intruding knee bolster bruising her shin, and her right ankle contacted the foot controls bruising her ankle. The driver remained restrained in her seat, and her upper torso most likely moved to her right and back opposite the case vehicle's 120 degree direction of principal force as the GMC's back right corner was impacted by the case vehicle's right front side. The driver remained restrained in her seat as the case vehicle came to final rest. She was entrapped in the case vehicle by the intruded instrument

panel and the downwardly displaced steering wheel (**Figure 18**). Rescue personnel removed the driver's door, and B-pillar, and cut her safety belt and the steering wheel rim to extricate her from the vehicle.

CASE VEHICLE DRIVER INJURIES

The case vehicle's driver was transported by ambulance to the hospital. She sustained moderate injuries and was treated and released. The driver stated she lost 30 work days as a result of the crash and received follow-up treatment with a bone specialist and a neurological specialist. The case vehicle driver's injuries and injury mechanisms are presented in the table below.



Figure 18: Intrusion of case vehicle's instrument panel and displacement of steering wheel entrapped driver legs

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with loss of consciousness of unknown duration, no recall of crash, and GCS=14	moderate 160410.2,0	Left "B"-pillar	Probable	Emergency room records
2	Fracture, complete, left mid-shaft clavicle with displacement and mild angulation	moderate 752200.2.2	Torso portion of safety belt system	Certain	Emergency room records
3	Laceration, 25 cm (9.8 in), left parietal scalp involving sub-cutaneous tissue; staples required for closure	moderate 190604.2,2	Left "B"-pillar	Probable	Emergency room records
4	Contusion {bruise} right shin, not further specified	minor 890402.1,1	Knee bolster, driver's, right of steering column	Probable	Interviewee (same person)
5	Contusion over right lower distal tibia and/or ankle	minor 890402.1,1	Floor, foot controls	Probable	Emergency room records

1ST OTHER VEHICLE

The 2004 Freightliner Columbia was a 6 x 4, cab-over truck-tractor (VIN: 1FUJA6CK24L-----) with a van semi-trailer. This vehicle was not inspected.

Exterior Damage: Based on the police on-scene photographs of the damage to the Freightliner, the TDC was estimated to be: **12-FYEW-2**. The Freightliner was towed due to damage.

Freightliner’s Occupants: According to the police crash report, the Freightliner’s driver [48-year-old, White (unknown if Hispanic) male]; was restrained by his three-point, lap-and-shoulder, safety belt system. The police crash report indicated the driver was not injured and was not transported from the crash scene.



Figure 15: Underride damage due to impact by case vehicle’s front right

2nd Other Vehicle

The 1994 GMC, C-1500 was a rear wheel drive, two-door, extended cab pickup truck (VIN: 2GTEC19K4R1-----) equipped with a 5.7L, V8 engine and four speed automatic transmission with overdrive. The GMC’s wheelbase was 359.4 centimeters (141.5 inches).



Figure 16: Induced damage to back of cab and bed

Exterior Damage: The GMC’s two impacts with the case vehicle involved the back end, with the damage involving the full width of the back bumper. In addition, there was underride damage to the left portion of the GMC’s undercarriage aft of the left rear wheel (**Figure 15**). The two impacts produced overlapping damage to the back bumper, so one set of crush measurements was taken to document to totality of the damage. The direct damage began at the left rear bumper corner and extended 174 centimeters (68.5 inches) across the bumper. The residual maximum crush was measured as 26 centimeters (10.2 inches) occurring at C₂. The table below shows the GMC’s back bumper crush profile.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	174	26	174	19	26	12	12	11	18	0	0
in		68.5	10.2	68.5	7.5	10.2	4.7	4.7	4.3	7.1	0.0	0.0

The GMC’s wheelbase was not altered due the impact. Induced damage involved the truck bed, back of the truck cab and left side of the truck cab behind the left front door (**Figure 16**).

The back left impact forced the truck bed forward, which impacted the back of the truck cab. The back end was also displaced upwards, primarily on the left side. No other induced damage or remote buckling was noted.

The GMC’s recommended tire size was: P235/75R15. The GMC was equipped with all terrain tires size 21x10.5R15LT. The GMC’s tire data are shown in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 nd of an inch			
LF	0	0	241	35	4	5	Rim abraded	No	Yes
RF	172	25	241	35	3	4	None	No	No
LR	200	29	241	35	3	4	None	No	No
RR	0	0	241	35	3	4	Sidewall cut	No	No

Damage Classification: Based on the vehicle inspection the CDCs for the GMC were determined to be: **06 BYEW-1 (180 degrees)** and **06-BZEW-1 (170 degrees)**. The WinSMASH reconstruction program could not be used to reconstruct the GMC’s Delta V because “chain reaction”, sustained contact collisions such as this crash are out of scope of the program.

GMC’s Occupants: According to the police crash report, the GMC’s driver [20-year-old, White (unknown if Hispanic) female]; was restrained by her three-point, lap-and-shoulder safety belt system. The driver sustained a police reported “C” (possible) injury and was not transported from the crash scene.

