

CRASH DATA RESEARCH CENTER

Calspan Corporation
Buffalo, NY 14225

CALSPAN ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION

CASE NO: CA07-031

VEHICLE: 2006 KIA OPTIMA

LOCATION: WEST VIRGINIA

CRASH DATE: SEPTEMBER 2007

Contract No. DTNH22-07-C-00043

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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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CALSPAN ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION

CASE NO: CA07-031

VEHICLE: 2006 KIA OPTIMA

LOCATION: WEST VIRGINIA

CRASH DATE: SEPTEMBER 2007

BACKGROUND

This on-site investigation focused on a rear-facing infant Child Safety Seat (CSS) and the fatal injury sources of a 2-month old male child restrained within the CSS. The CSS was installed without the detachable base in the second row right position of a 2006 Kia Optima (**Figure 1**). The Kia was struck on the left side by the front of a 1999 Dodge Neon in an intersection crash. The Kia then departed the right side of the road and impacted multiple fixed objects and overturned. The Kia was equipped with dual stage frontal air bags and seat back mounted side impact air bags for the driver and front right passenger positions, all of which deployed during the crash. The Kia was occupied by a 47-year old male driver, a 49-year old female front right passenger, a 26-year old female second row middle passenger, and the 2-month old male child passenger, who was placed within the CSS. The 2-month old child and the CSS were ejected from the vehicle through the right rear side as integrity was lost between the window frame and roof side rail. The child and CSS came to rest approximately



Figure 1 - 2006 Kia Optima at final rest.



Figure 2 - The final rest position of the CSS (outlined) in relation to the Kia Optima.

1.5 m (5 ft) west of the rest position of the vehicle (**Figure 2**). The child sustained bilateral cerebrum lacerations, multiple skull fractures, fractures of the left clavicle and humerus, and multiple soft tissue injuries while being ejected from the vehicle, and expired at the scene. He was pronounced deceased at the scene. The remaining three occupants were transported to a local hospital with non-life threatening injuries.

The crash was identified by the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) after receiving notification from a representative from the West Virginia Governor's Highway Safety Program. The police crash report was forwarded to the Calspan SCI team who located the vehicles and CSS and established cooperation with the investigating police agency. The case was assigned on October 10th for an on-site investigation. Both vehicles were located at a secured impound facility, and the CSS was in the possession of the investigating agency. The police agency allowed an inspection of the CSS and contacted the tow facilities allowing

for the release of the vehicles for inspection. The inspections took place during the week of October 15. The final report has been linked to the Electronic Data System (EDS).

SUMMARY

Crash Site

The two-vehicle crash occurred at a four-leg intersection that was controlled by stop signs for north/south traffic. At the time of the crash, the asphalt roadways were dry and there were no adverse weather conditions. The east/west roadway was configured with one lane in each direction and was delineated by a painted broken yellow centerline. Both lanes were 3.6 m (11.8 ft) in width and were bordered by white fog lines and gravel shoulders. A police station was located on the northwest corner of the intersection; directly in front of the station was an elevated parking lot with an outlying retaining wall. Dimensionally, the retaining wall was 12 m (39 ft) in length east to west, 6 m (20') in length north to south, 0.6 m (2 ft) in height and 0.2 m (0.5 ft) in width. Within the parking area were nine painted parking spaces for vehicles affiliated with the barracks. The posted speed limit for the roadway was 89 km/h (55 mph). The north/south roadway was configured without a centerline, but was designed with one travel lane in each direction. The north/south roadway was winding and experienced a positive 7 percent incline leading to the intersection. An unobstructed stop sign was positioned on the southeast corner of the intersection. The Crash Schematic is included as **Figure 29** at the end of this narrative report.

Vehicle Data – 2006 Kia Optima

The 2006 Kia Optima was configured as a four-door sedan and was identified by the Vehicle Identification Number (VIN): KNAGD126565 (production number omitted). The vehicle’s mileage could not be determined because of damage to the electrical system. The total GVWR was 1,955 kg (4,310 lb) with 1,080 kg (2,381 lb) distributed to the front axle and 875 kg (1,929 lb) distributed to the rear. The front wheel drive vehicle was equipped with a 4-cylinder, 2.4-liter engine linked to a four-speed automatic transmission. The vehicle was designed with four-wheel disc brakes without ABS. The vehicle was configured with 38 cm (15”) steel wheels and Kumho Steel Radial 722 P205/60R15 tires. The vehicle manufacturer’s recommended cold tire pressure was 207 kPa (30 PSI). The specific tire information at the time of the SCI inspection was as follows:

Position	Tire Pressure	Tread Depth	Damage
LF	Tire Flat	6 mm (7/32”)	Tear in sidewall
LR	Tire Flat	4 mm (5/32”)	Minor rim damage
RF	179 kPa (26 PSI)	5 mm (6/32”)	Tear in sidewall and restricted
RR	Tire Flat	4 mm (5/32”)	De-beaded and aired out with rim damage

The 2006 Kia Optima was configured with front bucket seats with adjustable head restraints. The deformation of the floor pan prevented the measuring of the frontal seat track positions. The driver’s seat appeared to be at the full rear track position and the

right front seat was adjusted to 5 cm (2") forward of full rear. The distance between the driver's seat back and the steering column hub measured 61 cm (24"). The distance between the front right seat back the midpoint of the knee bolster was 76 cm (30").

The second row consisted of a full length bench seat with adjustable head restraints for all three seating positions. The longitudinal distance between the rear seatback and the front seat backs was 73 cm (29") at the second row left and center positions and 69 cm (27") at the right rear position. The right rear seat cushion was compressed laterally 11 cm (4.5") due to the intrusion of the right rear door panel.

Vehicle Data – 1999 Dodge Neon

The 1999 Dodge Neon was configured as a four-door sedan and identified by the VIN: 1B3ES47C1XD (production number omitted). The vehicle's GVWR was 1,590 kg (3,505 lb) with 885 kg (1,951 lb) distributed to the front axle and 729 kg (1,607 lb) distributed to the rear. The front wheel drive vehicle was powered by a 4-cylinder, 2.0-liter engine linked to a three-speed automatic transmission. The vehicle was equipped with 36 cm (14") steel wheels and P185/65R14 tires with various manufacturers. The vehicle manufacturer's recommended cold tire pressure was 207 kPa (30 PSI). The front right wheel was missing from the vehicle at the time of the SCI inspection. The specific tire information was as follows:

Position	Tire Make/Model	Tire Pressure	Tread Depth	Damage
LF	Lexington ES – 335	124 kPa (18 PSI)	4 mm (5/32")	None
LR	Uniroyal Radial A/S	165 kPa (24 PSI)	6 mm (7/32")	None
RF	Unknown	Unknown	Unknown	Missing
RR	Uniroyal Radial A/S	179 kPa (26 PSI)	6 mm (7/32")	None

Crash Sequence

Pre-Crash

The 47-year old male driver of the Kia was traveling in a westerly direction on the two-lane roadway and was approaching the four-leg intersection (**Figure 3**). The driver of the Kia was intending to continue straight through the intersection. The Dodge was traveling north approaching the same intersection, disregarded a stop sign and attempted to turn left (**Figure 4**). The driver of the Kia reacted to the impending crash by applying and locking the brakes, which was evidenced by a 6 m (20') skid mark on the roadway. The skid mark was attributed to the front right tire.



Figure 3 - Westbound approach of the Kia.



Figure 4 - Northbound approach of the Dodge Neon.

Crash

The left side of the Kia was impacted by the front plane of the Dodge within the four-leg intersection. The directions of force for the Kia and Dodge were in the 10 o'clock and 1 o'clock sectors, respectively. The impact resulted in moderate damage to both vehicles that was sufficient to deploy the left front seat back mounted side air bag in the Kia. The frontal air bags also deployed as a probable result of the left rear wheel of the Kia as it became snagged to the front plane of the Dodge, which created a sufficient longitudinal velocity change to deploy the air bags. The damage algorithm of the WinSMASH program computed a total delta-V of 15 km/h (9.3 mph) for the Kia and 18 km/h (11.2) for the Dodge. The specific longitudinal and lateral velocity changes were -5 km/h (-3.1 mph) and 14 km/h (8.2 mph) for the Kia and -16 km/h (-9.9 mph) and -9 km/h (-5.5 mph) for the Dodge.

The force of the impact was rearward of the Kia's center of gravity, which caused the Kia to rotate CCW and off-track toward the north roadside (**Figure 5**). Both right side tires left yaw marks on the north shoulder and grassy roadside as the vehicle side-slipped to the right. The yaw mark attributed to the front right tire measured 5.8 m (19 ft) in length and was slightly CCW in orientation. It began slightly outboard of the white fog line and terminated slightly inboard of the grassy roadside. The yaw mark attributed to the right rear tire measured 3 m (9.8 ft) in length and began where the roadway transitioned from asphalt to soft soil on the roadside. During this CCW rotation, the vehicle's center of gravity shifted to the right and additional load was transferred to the outboard sidewalls of right side tires. The sidewall of the right rear tire rolled under the right rear wheel and the tire de-beaded resulting in an air out. The front right rim sustained direct contact damage from roadway interaction but the tire did not flatten. The front rim contact and the de-beading of the right rear wheel caused the vehicle to begin to overturn.



Figure 5 - Post-impact trajectory of the Kia, including the impacted guard post, retaining wall, and the area of final rest.

A guard post was located just beyond the termination point of the right rear tire yaw mark in the direct path of the Kia. The post was 13 cm (5") in diameter and 88 cm (34.5") in height. It was impacted by the Kia causing damage to the right rear door of the vehicle as the trip began. This is supported by associative evidence to the right side of the Kia and damage to the CSS. The associative evidence outlined above is addressed in the Exterior Damage and Child Safety Seat sections of this narrative. Based on damage patterns to the vehicle, however, it was surmised that the vehicle initially maintained a horizontal orientation as it impacted the steel post (approximately a 10 degree roll angle at the point of initial impact with the post). Because the impact remained in the horizontal range, a Barrier algorithm of the WinSMASH program was completed for this event. The direction of force for this impact was in the 2 o'clock sector. The program computed a total delta-V of 9 km/h (5.5 mph) with longitudinal and lateral velocity changes of -3

km/h (-1.9 mph) and -8 km/h (-5 mph). The impact was sufficient to deploy the front right seatback mounted side air bag.

As the Kia impacted the post rearward of its center of gravity, it reversed its rotation to clockwise and began to override the post and overturn at a greater roll rate. The vehicle vaulted over the post and became partially airborne. The Kia traveled 3 m (9.8 ft) and impacted the 0.6 m (2 ft) concrete retaining wall, located beyond of the guard post. The roll rate of the Kia when it impacted the wall was approximately 120 degrees. The right side, right A-pillar, and hood areas impacted the wall resulting in moderate damage. While straddling the wall the vehicle continued rotating CW sustaining moderate damage to its roof and left side in the area of the C-pillar. After sliding on its roof along the wall a distance of 5 m (16 ft), the vehicle separated and fell to the ground. The roof of the vehicle contacted two parking signs that were located just outboard of the retaining wall. The vehicle came to rest on its roof beside the retaining wall facing in the northeast direction. The child passenger and the CSS were ejected from the vehicle during the roll sequence. The CSS came to rest on its shell in an upright position with the child still harnessed within it 1.5 m (5 ft) west of the vehicle.

Post-Crash

Emergency personnel arrived on-scene and removed the three adult passengers from the Kia. The two front row passengers and the second row middle female passenger were transported to a local hospital for treatment and then released. The driver sustained soft-tissue injuries, while the front right and second row middle passengers sustained a combination of fractures and soft-tissue injuries. The 2-month old male child expired prior to the arrival of emergency personnel and was pronounced deceased at the scene. After a brief evaluation at a local hospital, the child's body was transferred to the county coroner's office. Both vehicles were towed from the scene and impounded by the investigating agency.

Vehicle Damage

Exterior Damage – 2006 Kia Optima

The 2006 Kia Optima sustained moderate damage at several locations due to the multiple impact crash (**Figure 6**). The initial area of impact was to the vehicle's left side; specifically, the direct damage began 13 cm (5") aft of the front left axle and extended rearward for 269 cm (106"). There was no induced left side damage outside of the direct damage pattern. The maximum crush was located 121 cm (48") aft of the front left axle and measured 19 cm (7.5") in depth. The crush profile consisted of six equidistant crush measurements taken along the sill and was as follows: C1 = 1 cm (0.5"), C2 = 13 cm (5"), C3 = 19 cm (7.5"), C4 = 9 cm (3.5"), C5 = 4 cm (1.2"), C6 = 4 cm (1.2"). The Collision Deformation Classification (CDC) for the impact with the 1999 Dodge Neon was 10-LDEW-2. The left rear wheel snagged the Dodge's



Figure 6 - Front and left side planes of the Kia Optima.

front end and elongated the wheelbase, which further induced the vehicle's post-impact CCW rotation.

The second impact to the 2006 Kia Optima was a right side impact with a 13 cm (5") diameter guard post (**Figures 7 and 8**). The impact resulted in moderate damage to the right rear door area of the vehicle. The direct contact damage began 36 cm (14.2") forward of the right rear axle and measured 30 cm (11.8") in width. The combined direct and induced damage began 20 cm (7.8") forward of the right rear axle and measured 71 cm (30") in width. The maximum crush was located 46 cm (18.1") forward of the rear axle and crushed laterally to a depth of 20 cm (7.8"). The crush profile consisted of six equidistant measurements taken along the sill. The sill was utilized because the right rear door panel was deformed outward of the vehicle's beltline. The crush profile was as follows: C1 = 3 cm (1.2"), C2 = 20 cm (7.8"), C3 = 14 cm (5.5"), C4 = 6 cm (2.4"), C5 = 3 cm (1.2"), C6 = 0 cm. The CDC for this impact was 02-RPAN-2.



Figure 7 - Overall view of the right side of the Kia Optima.



Figure 8 - Direct contact damage from the impact with the guard post.

It was determined that the Kia was partially non-horizontal during the impact with the guard post. It was estimated to be approximately 10 degrees from horizontal based on the greater depth of the door crush along the beltline of the vehicle opposed to the lower aspects of the door. Additionally, considering that the guard post was 88 cm (34.5") in height and the beltline of the vehicle was 105 cm (41.3") in height, the vehicle had to have been angled toward the object at impact. Furthermore, tire evidence at the scene of the crash terminated at the point the vehicle impacted the post which suggested that the vehicle began to overturn. It should be noted that the window frame deformed outboard of the vehicle, which resulted in a 54 cm (20") opening between the window frame and the roof side rail. This opening was the likely ejection portal of the right rear child passenger.

The Kia sustained multiple areas of damage to its front, back, left side, right side, and top planes during the rollover onto the retaining wall. The damage to the front (**Figure 9**) was present in two locations with the first beginning at the left front bumper corner and extending 46



Figure 9 - Frontal plane of the Kia Optima.

cm (18") to the right. The damage extended diagonally across the vehicle's hood, separating briefly and then reengaging along the right aspect of the windshield and the right A-pillar. The area of damage to the hood measured 86 cm (34") longitudinally and 28 cm (11") laterally at its widest point. Associative yellow paint from the curbs within the parking spaces of the police station parking lot was embedded within the damage. The windshield was holed 43" (17") vertically and 13 cm (5") laterally from this impact. The second area of damage to the hood began at the centerline of the vehicle and also extended in a diagonal orientation longitudinally for 76 cm (30") and laterally for 23 cm (9"). Both areas of damage contained white powder residue from the concrete wall.

In addition to the left side damage sustained during the impact with the Dodge, the left side of the Kia sustained moderate damage at two separate locations, which resulted from the rollover event along the retaining wall (**Figure 10**). The first area of damage began at the left front bumper corner and extended along the fender rearward 69 cm (27"). The left front wheel sustained multiple tears to the sidewall and the rim displayed numerous vertical striations and several gouges. The second area of damage began at the junction of the left front



Figure 10 -Left rear oblique view of the Kia Optima.

A-pillar and roof side rail and extended the full width of the vehicle rearward to the left rear bumper corner. The area of deepest lateral crush associated with this damage was located in the C-pillar zone at the junction of the C-pillar and roof side rail, and was 11 cm (4.5") in depth. The left rear wheel was deformed rearward elongating the wheelbase by 22 cm (8.7"). The wheel also had a positive camber of approximately 30 degrees. Associative vertical, lateral, and longitudinal striations as well as concrete powder transfers were present along the majority of the left side plane. Layered earth also surrounded the left roof side rail and the C-pillar area of the vehicle. The left side damage detailed above was consistent with the rollover event.

In addition to aforementioned right side impact with the guard post, the right side of the Kia sustained multiple areas of striations as a result of the rollover event. The first area of damage was located on the front right fender and consisted of a 28 x 30 cm (11 x 12") area of vertical striations and surface scratching. Further rearward, a distinct narrow pattern of damage began at the lower aspect of the B-pillar and extended diagonally 124 cm (49") to the base of the A-pillar. Associative white powder transfers and striations were also present, attributable to the retaining wall.



Figure 11 - Damaged roof and C-pillar of the Kia Optima.

The roof of the Kia sustained moderate damage as a result of the simultaneous events of the rollover

and a non-horizontal top impact to the retaining wall (**Figure 11**). The direct contact damage along the roof began at the vehicle's centerline and extended laterally to the left roof side rail 58 cm (22.6"). The damage extended longitudinally 127 cm (50"), the full length of the roof. The maximum vertical crush was located in the C-pillar zone and measured 17 cm (6.5") in depth. The crush profile consisted of six equidistant crush measurements taken vertically from the roof side rail and was as follows: C1 = 17 cm (6.5"), C2 = 10 cm (4"), C3 = 1 cm (0.5"), C4 = 1 cm (0.5"), C5 = 1 cm (0.5"), C6 = 1 cm (0.5"). Two CDC's were assigned to the roof due to the simultaneous events. The CDC for the rollover event was 00-TDDO-3 and the CDC for the top impact was 00-TDYW-3.

Two subsequent CDC's were assigned to the roof as a result of the impacts to the parking signs located outboard of the retaining wall. The exact damage locations from the sign impacts were obscured by overlapping damage; however, the on-scene images revealed that the CDC's for both events were 00-TFDN-1.

Interior Damage – 2006 Kia Optima

The 2006 Kia Optima sustained moderate interior damage as a result of passenger compartment intrusion. The area of greatest intrusion was to the right front window frame which intruded vertically 28 cm (11") as a result of the top impact to the retaining wall. The window frame and seven additional intrusions were identified and are detailed by their magnitude below:

Position	Intruded Component	Magnitude	Direction
Front right	Window frame	28 cm (11")	Vertical
Second row right	Door panel	14 cm (5.5")	Lateral
Second row left	Roof	11 cm (4.5")	Vertical
Second row left	Roof side rail	10 cm (4")	Vertical
Second row left	Backlight header	10 cm (4")	Vertical
Front right	A-pillar	9 cm (3.5")	Vertical
Second row middle	Roof	3 cm (1")	Vertical

The inboard aspect of the right rear door of the 2006 Optima exhibited three discernable areas of probable contact with the CSS (**Figure 12**). A scratch was present on the plastic door panel. The scratch was 1 cm (0.5") in length and located 17 cm (6.7") forward of the rear aspect of the door panel. It is probable that the scratch occurred as the door intruded and contacted the CSS. A linear oriented tear was present on the fabric of the inboard door panel. The tear was 1 cm (0.5") in length and was located 62 cm (24.4") aft the B-pillar. A longitudinally oriented 38 cm (15") abraded crack was present along the beltline of the door panel. It began 30 cm (11.8") aft of the B-pillar and terminated 68 cm (27") aft of the same. A lone hair was identified at the mid aspect of the roof side rail consistent with the ejection path of the child.

The roof and interior in general exhibited large areas of body fluid transfers attributable to the head injuries sustained by the right rear child passenger. The body fluid and matter transfers were present in every region of the vehicle and were particularly heavy on the roof liner. Musical production equipment consisting of a sound system and turn table [estimated to weigh 23 kg (50 lb)] was placed on the seat cushion in the second row left seating position (**Figure 13**). An 11 x 10 cm (4.5 x 4") gouge was present on the roof slightly aft of the dome light, and the dome light cover was missing. The gouge occurred during the rollover as a result of contact from the musical equipment. An extensive amount of body fluids pooled within the equipment post-crash.



Figure 12 - Inboard aspect of the right rear door panel.



Figure 13 - Musical equipment inside of the Kia Optima.

Exterior – 1999 Dodge Neon

The 1999 Dodge Neon sustained moderate damage as a result of the impact with the Kia Optima (**Figure 14**). The direct contact damage and the combined direct and induced damage extended from the left bumper corner to right bumper corner. The bumper cover and energy absorption material separated from the reinforcement bar; therefore, the rebar was utilized as the Field L and to generate the crush profile. The rebar measured 119 cm (46.9") in length and the undeformed end width was 142 cm (56"). The maximum crush was located at the vehicle's centerline and measured 14 cm (5.5") in depth. The crush profile consisted of six equidistant measurements taken along the rebar and was as follows: C1 = 10 cm (4"), C2 = 12 cm (5.25"), C3 = 14 cm (5.5"), C4 = 14 cm (5.5"), C5 = 10 cm (4"), C6 = 9 cm (3.5"). The CDC for the impact with the Kia was 01-FDEW-1. **Figures 15 and 16** are on-scene views of the Dodge Neon at final rest.



Figure 14 - Frontal damage to 1999 Dodge Neon.



Figure 15 – Frontal damage and the on-scene final rest position of the Dodge Neon.



Figure 16 - Damage and final rest position of the Dodge Neon

Manual Restraints – 2006 Kia Optima

The 2006 Kia Optima was configured with manual 3-point lap and shoulder belts for all five seating positions. The driver's belt was configured with an Emergency Locking Retractor (ELR) while the remaining four safety belts utilized switchable ELR/Automatic Locking Retractors (ALR's). Both front belts had sliding latch plates, adjustable D-rings, and retractor pretensioners that actuated during the impact. The frontal belts were locked into the worn position by the actuation of the pretensioners and exhibited stretching consistent with usage during the crash.

The second row belts were configured with sliding latch plates. The right rear lap belt was used to install the CSS without the attachable base in the right rear seating position. The lap belt was routed across the belt paths on the forward aspect of the CSS. Post-crash, the right rear belt remained buckled with the latch plate still engaged with the receiver (**Figure 17**). The investigating police officer advised that since the CSS was completely ejected from the vehicle there was no need to unlatch the belt system post-crash. In this position, the slack in the lap belt from the anchor point to the latch plate engaged in the buckle measured 71 cm (28"). The full length of the right rear belt webbing was 220 cm (90"). The switchable retractor was fully operational and in the ELR mode at the time of the SCI inspection. Body fluid transfers were present along the lower half aspect of the belt webbing, which began at the anchor point and extended upwards 104 cm (41"). A small tear was also present on the webbing; it was located 15 cm (6") above the anchor point and measured 1 cm (0.5") in length (**Figure 18**).

It was determined during the SCI inspection that the second row left and middle belts were not used during the crash. Both belts were restricted in an unused position inside the vehicle. The left C-pillar, although not intruded, slightly deformed thereby inhibiting movement of the left rear belt. The belt in the second row middle position was restricted in place, taut along the seat back, and thereby precluded the belt from spooling out.



Figure 17 - Engaged right rear lap and shoulder belt.



Figure 18 - Small tear in lap belt webbing.

Frontal Air Bag System - 2006 Kia Optima

The 2006 Kia Optima was equipped with frontal air bags for the driver and front right passenger positions. The driver's air bag was housed in the center of the steering wheel hub. The driver's air bag deployed through symmetrical H-configuration cover flaps. The flaps measured 15 cm (6") in width and 8 cm (3") in height. The driver's air bag measured 55 cm (22") in diameter in its deflated state and had an excursion of 30 cm (12"). The bag had two tether straps and was vented by ports in the 11 and 1 o'clock sectors. A 1 cm (0.5) diameter scuff was present on the vertical centerline of the air bag, 2 cm (0.8") above the horizontal centerline. Body fluids associated with the infant were located on the left aspect of the air bag, which began 18 cm (7.1") left of the vertical centerline and extended 8 cm (3") to the outer edge of the bag. The following nomenclature was stamped on the back aspect of the air bag:

AES 0727 10189

RA 66

The front right air bag deployed from a mid-mount module hinged at the top aspect. The cover flap was rectangular and measured 30 cm (12") in width and 15 cm (6") in height. The air bag was symmetrically designed and measured 56 cm (22") in height and width. The air bag was internally vented and tethered by a single strap that was 29 cm (11.5") in width. There was no discernable contact evidence to the air bag.

Side Air Bag System - 2006 Kia Optima

The 2006 Kia Optima was equipped with seat back mounted side air bags for the driver and front right passenger seating positions. The air bags were trapezoidal in shape and deployed from 46 cm (18") tear seams on the front seat backs. The inboard panels of the air bags, contiguous to the seat back, measured 46 cm (18") in height; the parallels measured 50 cm (20") in width; and the outboard edges measured 36 cm (14") in height. Body fluid transfers were present on both side air bags in multiple locations. The fluid and matter transfers were attributed to the right rear child passenger.

Child Safety Seat

A Dorel/Eddie Bauer Designer 22 infant CSS was installed rear-facing in the second row right side position of the 2006 Kia Optima (**Figure 19**). The CSS was installed inside the vehicle with the manual shoulder belt and without the detachable base. The CSS was ejected from the vehicle during the crash and was inspected at the police department during the on-site SCI investigation. The CSS model number was 22-625 GDC and the date of manufacture was 01/18/2005. The CSS was configured with a 5-point internal harness system and a two-piece chest retainer clip. The CSS was rated for infants weighing between 2.3 km (5 lb) and 10 km (22 lb) and between 48 cm (19”) and 74 cm (29”) in height.



Figure 19 - Dorel/Eddie Bauer Designer 22 Infant CSS.

The CSS sustained severe damage as a result of becoming unrestrained and struck by the vehicle during the rollover sequence. Damage consisted of multiple fractures to all sides of the CSS shell as well as torn fabric and a fractured right belt path. The CSS had four slots to adjust the internal harness straps and the investigation revealed that the harness straps were routed through the slots at the third level from the top. Based on police images, the retainer chest clip was adjusted to slightly below the armpit level of the child.

The manual lap and shoulder belt was still engaged within the buckle at the time of the SCI inspection. The slack in lap belt portion of the webbing measured 71 cm (28”). Using an exemplar vehicle and CSS, it was determined that 76 cm (30”) of lap belt webbing was required to correctly install the rear-facing CSS using the designated belt paths. During the impact with the post, the right rear door intruded into the passenger compartment and compressed the right rear seat 11 cm (4.5”). This intrusion also caused the belt’s anchor point to move inboard and created additional slack in the lap belt.

The combination of the slack and crash forces allowed the lap belt to become free of the left belt path. The intruding door contacted the lower forward aspect of the CSS shell resulting in stress marks [an area of 11 x 11 cm (4.5 x 4.5”)] to the CSS (**Figure 20**). The lap belt was still engaged within the right belt path; however, as the CSS responded to the crash forces, the right belt path fractured (**Figure 21**). After the fracture of the belt path, the CSS became disengaged from the belt system and was partially ejected from the right side of the vehicle during the subsequent crash events.



Figure 20 - Stress marks on lower left frontal aspect of the CSS shell.

The ejection portal was the right rear window of the vehicle. The window frame deformed outward and separated from the contour of the vehicle creating a 50 cm

(20") gap between it and the roof side rail. As the vehicle rolled two-quarter turns, the CSS and child's head were contacted by the vehicle. Body fluid transfers were found within the parking stalls of the police barracks parking lot following the crash. Additional damage to the CSS is outlined below.



Figure 21 - Fractured right belt path.

The top of the CSS revealed surface scratching and torn fabric at the uppermost aspect of the CSS. The tear to the fabric encompassed the entire top aspect and was 35 cm (14") in width. Blue, yellow, and red substance transfers were present within the fabric of the CSS (**Figure 22**). The parking space lane lines in the area of the body fluid transfers on the cement were painted blue and the parking curbs within the parking spaces were painted yellow. It is probable that transfers to the top aspect fabric of the CSS occurred as it was partially ejected from the vehicle. A fabric abrasion was also identified 20 cm (8") below the top of the CSS. This is the area where the child's head would be positioned. The abrasion is consistent with contacting concrete and had white dust particles embedded within the fabric (**Figure 23**). Associative body fluid transfers were prevalent within this area of the CSS as well.



Figure 22 - Damage and paint transfers to the top of CSS.



Figure 23 - White substance transfers to the front of the CSS.

In addition to the aforementioned fracture of the right belt path, the right side of the child seat revealed a 10 cm (4") longitudinally oriented fracture to the lower rear aspect of the shell, aft of the arch designed to engage the CSS base. A 9 cm (3.5") semi-circular fracture was present on the lower aspect of the right side carrying handle slightly above the handle adjuster (**Figure 24**). Additional scuffing and scratching was located along the right side surface of the shell indicative of engaging the abrasive surface of the retaining wall. An underlying 10 cm (4") diagonally oriented fracture to the shell of the CSS was present beneath the fractured belt path



Figure 24 - Damage to the mid right side aspect of the CSS.

The left side of the CSS sustained additional damage which included a fracture at the base of the carrying handle, additional fractures to the shell, and torn fabric at multiple locations. An 8 cm (3") vertically oriented fracture began at the base of the carrying handle adjuster and extended downward to the base attachment of the CSS (**Figure 25**).



Figure 25 - Damage to the mid left aspect of the CSS.

The back and underside of the shell sustained multiple fractures and concentrated areas of surface scratching. Both outboard aspects of the shell sustained vertically oriented fractures during the crash (**Figure 26**). The fracture to the left outboard aspect of the CSS began 21 cm (8.3") below the top aspect of the CSS and extended downward 11 cm (4.5"). The fracture to the right outboard aspect of the shell began 12 cm (4.5") below the top aspect and extended downward 44 cm (17"). An additional 22 cm (8.7") long diagonally oriented fracture, which emanated from the lower right aspect and terminated at the upper left aspect, was identified (**Figure 27**). Areas of surface scratching from concrete were present in several areas on the back and underside of the shell consistent from contacting an abrasive material such as concrete.



Figure 26 - Dual fractures to the back of the CSS.



Figure 27 - Diagonally oriented fracture to the back of the CSS.

Occupant Demographics

Driver

Age/Sex: 47-year old/Male
Height: Unknown
Weight: Unknown
Seat Track Position: Full-rear
Manual Restraint Usage: 3-point manual lap and shoulder belt
Eyewear: Unknown
Type of Medical Treatment: Transported to area hospital and released

Driver Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Abrasion to right temple (parietal region)	Minor (190202.1,1)	Occupant-to-occupant contact
Right posterior head laceration and contusion	Minor (190602.1,1) (190402.1,1)	Occupant-to-occupant contact
Left hand abrasion and contusion	Minor (790202.1,2) (790402.1,2)	Left instrument panel

Source: Hospital records.

Driver Kinematics

The restrained 47-year old driver was seated in the front left seat in a presumed upright posture. At impact, the driver's frontal and seat back mounted side air bags deployed and the retractor pretensioners actuated. The driver loaded the safety systems and rode down the forces of the crash. It is probable that his left hand contacted the left instrument panel as he sustained an abrasion and contusion to this left hand. As the vehicle overturned, the driver was probably contacted by the front right occupant, which resulted in a laceration, abrasion, and contusion to his head. He was transported to a local hospital where he was treated for his injuries and released.

Front Right Passenger

Age/Sex: 49-year old/Female
Height: Unknown
Weight: Unknown
Seat Track Position: 5 cm (2") forward of full-rear
Manual Restraint Usage: 3-point manual lap and shoulder belt
Eyewear: Unknown
Type of Medical Treatment: Transported to an area hospital and released

Front Row Right Passenger Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Left radius fracture	Moderate (752802.2,2)	Roof
Neck contusion and abrasion	Minor (390402.1,1) (390202.1,1)	Shoulder belt restraint webbing
Chest contusion	Minor (490402.1,1)	Shoulder belt restraint webbing
Abdomen contusion	Minor (590402.1,0)	Shoulder belt restraint webbing
Cervical spine strain	Minor (640278.1,6)	Impact forces

Source: Hospital records.

Front Right Passenger Kinematics

The 49-year old female passenger was seated in the front right seat in a presumed upright posture. At impact, the front right passenger's frontal and seat back mounted side air bags deployed and the retractor pretensioners actuated. The front right passenger loaded the safety systems and rode down the forces of the crash. As a result of loading the restraint system, she sustained a contusion and abrasion to the right side of neck, a chest contusion, contusions to the lower and upper quadrants of her abdomen, and a cervical spine strain. As the vehicle overturned, the front right passenger's left arm contacted the roof resulting in a radius fracture. She was transported from the scene to a local hospital where she was treated for her injuries and released.

Second Row Center Passenger

Age/Sex: 26-year old/Female
 Height: Unknown
 Weight: Unknown
 Seat Track Position: Not adjustable
 Manual Restraint Usage: None
 Eyewear: Unknown
 Type of Medical Treatment: Transported to an area hospital and released

Second Row Center Passenger Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Right ulna open fracture (olecranon)	Serious (753204.3,1)	Right B-pillar
Distal and proximal fractures of the left radius	Moderate (752802.2,2) (752802.2,2)	Musical equipment in second row
Left elbow laceration	Minor (790600.1,2)	Musical equipment in second row
Lumbar spine strain	Minor (640678.1,8)	Impact forces

Source: Hospital records.

Second Row Center Passenger Kinematics

The unrestrained 26-year old female passenger was seated in the second row center seat in a presumed upright posture. At impact with the Dodge, she was displaced slightly to the left in response to the 10 o'clock direction of force. Post-impact rotation and the impact with the guard post redirected her to the right and it is probable that she loaded the right side door panel and B-pillar. As the Kia overturned, her right arm contacted these components and she sustained a comminuted fracture to the right ulna in the area of the olecranon. The unsecured musical equipment that was stowed in the second row left position likely contacted her, which resulted in distal and proximal fractures to her left radius and a left elbow laceration. As a result of impact forces during the crash, she also sustained a lumbar spine strain. The second row center passenger was removed from the vehicle by rescue personnel and transported to local hospital for treatment. She was released for the hospital later the same day.

Second Row Right Passenger

Age/Sex: 2-month old/Male
Height: 58 cm (23")
Weight: 6 kg (14 lb)
Seat Track Position: Not adjustable
Manual Restraint Usage: 3-point manual lap and shoulder belt with CSS
Eyewear: None
Type of Medical Treatment: None

Second Row Right Passenger Injuries

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Right cerebrum laceration	Severe (140688.4,1)	Concrete retaining wall
Left cerebrum laceration	Severe (140688.4,2)	Concrete retaining wall
Anterior vault skull fracture	Serious (150404.3,5)	Concrete retaining wall
Right vault skull fracture	Serious (150404.3,1)	Concrete retaining wall
Posterior vault skull fracture	Serious (150404.3,6)	Concrete retaining wall
Left clavicle fracture	Moderate (752200.2,2)	CSS harness
Left humerus fracture	Moderate (752602.2,2)	Concrete retaining wall
Eyelid abrasion	Minor (297202.1,1)	Concrete retaining wall
Laceration to left hand	Minor (790600.1,2)	Concrete retaining wall
Abrasion to right cheek	Minor (290202.1,1)	Concrete retaining wall

Injury	Injury Severity (AIS90/Update 98)	Injury Source
Abrasions to chin, left mandible region	Minor (290202.1,8)	Concrete retaining wall
Avulsion of right upper face, medial left upper face extending between the right auricular region and the mid portion of the left eyebrow.	Minor (290800.1,7)	Concrete retaining wall
Scalp avulsion in the area of the right temple	Minor (190800.1,1)	Concrete retaining wall
Right eyelid avulsion	Minor (297802.1,1)	Concrete retaining wall
Bi-occipital scalp laceration	Minor (190600.1,6)	Concrete retaining wall
Neck abrasion	Minor (390202.1,2)	CSS harness
Abrasion to left upper back	Minor (690202.1,2)	CSS shell
Small abdomen puncture	Minor (590600.1,8)	Concrete retaining wall
Multiple abdominal abrasions	Minor (590202.1,0)	Concrete retaining wall
Contusion to left upper abdomen	Minor (590402.1,7)	Concrete retaining wall
Abrasion to left upper chest	Minor (490202.1,2)	Concrete retaining wall
Contusion to medial left upper chest	Minor (490402.1,2)	CSS harness
Abrasion to anterior left shoulder	Minor (790202.1,2)	CSS shell
Laceration to anterior left shoulder	Minor (790602.1,2)	CSS shell
Multiple bilateral arm abrasions	Minor (790202.1,3)	Concrete retaining wall
Multiple left leg abrasions	Minor (890202.1,2)	Concrete retaining wall
Multiple left leg contusions	Minor (890402.1,2)	Concrete retaining wall

Source: External autopsy records.

Second Row Right Passenger Kinematics

The 2-month old child passenger was seated in the right rear position within a rear-facing infant CSS. He was restrained by the internal 5-point harness, with the retainer clip adjusted to slightly below the armpit level. The CSS was installed into position with the 3-point manual lap and shoulder belt. At impact with the Dodge Neon, the CSS was not markedly displaced as the lateral Delta-V was relatively low. Following the initial impact, the vehicle



Figure 28 - Intruding right rear door panel, crush to the sill, and compressed right rear seat.

rotated CCW, its wheels dug into the soft roadside soil and it began to partially overturn. As it was partially overturning, its right side impacted an 88 cm (34.5") guard post that was located on the right roadside. The impact resulted in crush that pocketed in the area of the rear aspect of the right rear door. This impact resulted in 11 cm (4.5") of intrusion to the right rear door and it compressed the right seat cushion (**Figure 28**). As this occurred, the CSS was also compressed, resulting in stress marks to the lower left frontal aspect. Additionally, the impact caused the outboard anchor of the safety belt to deform inboard. Slack in the belt webbing was introduced and the safety belt disengaged from the left belt path. During the dynamic movement of the CSS in relation to the crash forces, the right belt path fractured.

As the vehicle overturned right side leading, it impacted the retaining wall while at a roll angle of approximately 120 degrees from horizontal. The child and the CSS shifted laterally to the right and upward over the beltline of the vehicle. The vehicle overturned onto its top and straddled the retaining wall and parking area a distance of approximately 15 m (16 ft). The CSS, with the child still internally harnessed, was partially ejected through the right rear window area and caught underneath the vehicle as it straddled the retaining wall and parking area of the police station. While engaged with its top plane against the retaining wall, the Kia rotated CCW approximately 180 degrees, separated from the wall, impacted two parking signs, and came to rest facing northeast. The CSS came to rest upright 1.5 m (5 ft) from the Kia. The child remained harnessed within the CSS with his feet facing the vehicle. The child sustained left and right cerebrum lacerations, multiple skull fractures, fractures to the left clavicle and humerus, and multiple soft tissue injuries from becoming caught between the concrete retaining wall and the vehicle. The child was pronounced deceased by emergency personnel at the scene. The child was transferred to the county medical examiner's office following a brief evaluation at a local hospital. The autopsy consisted of an external examination only.

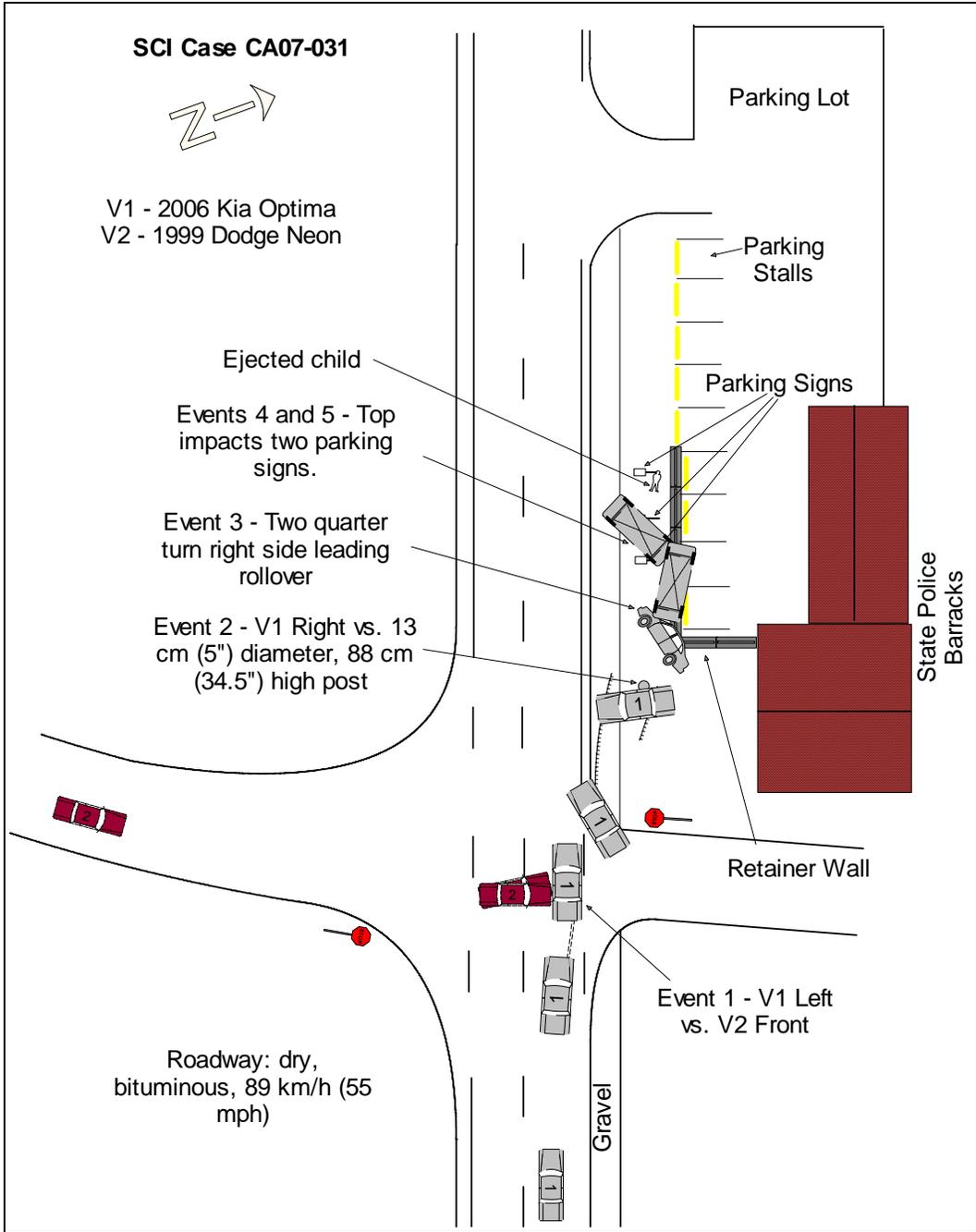


Figure 29 – Crash Schematic